Designation: A 31 – 00

Standard Specification for Steel Rivets and Bars for Rivets, Pressure Vessels

This standard is issued under the fixed designation A 31; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope *

1.1 This specification covers steel rivets for use in boilers and pressure vessels and steel bars for use in the manufacture of rivets.

1.2 Two grades are covered:

1.2.1 Grade A—Bars having a yield point of 23 000 psi (160 MPa) minimum with no controls on carbon content.

1.2.2 Grade B—Bars having a yield point of 29 000 psi (200 MPa) minimum with carbon 0.28 % maximum.

1.2.3 Rivets are manufactured from the applicable bar grade.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:

A 29/A29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

2.2 ANSI/ASME Standards:

B18.1.1 Small Solid Rivets 1/16 Inch Nominal Diameter and Smaller

B18.1.2 Large Rivets 1/2 Inch Nominal Diameter and Larger

B18.24.1 Part Identifying Number (PIN) Code System

3. Ordering Information

3.1 Orders for rivets and bars under this specification shall include:

3.1.1 ASTM designation and date of issue,

3.1.2 Quantity—Number of pieces for rivets and weight for bars,

3.1.3 Name of product and grade (A or B),

3.1.4 Size (diameter and length),

3.1.5 Rivet head type,

3.1.6 If inspection at point of manufacture is required,

3.1.7 Certification, if required (Section 14), and

3.1.8 Additional testing or special requirements, if required.

3.1.9 For establishment of a part identifying system, see ASME B18.24.1.

Note 1—A typical ordering description is: ASTM A 31 – 82, 10 000 pieces, steel rivets Grade A, 1/2 by 2 in., button head, test reports required.

4. Materials and Manufacture

4.1 The steel shall be made by any of the following processes: open-hearth, electric-furnace, or basic-oxygen.

4.2 Rivets shall be manufactured from rivet bars conforming to the applicable grade ordered.

4.3 Rivets shall be manufactured by hot- or cold-heading.

4.4 Bars shall be furnished as rolled and not pickled, blast cleaned, or oiled. At producer’s option, bars may be cleaned for inspection or cold drawn.

5. Chemical Composition

5.1 The steel shall conform to chemical composition prescribed in Table 1.

5.2 Heat Analysis—An analysis of each heat of steel shall be made by the bar manufacturer to determine for Grades A and B the percentages of carbon, manganese, phosphorus, and sulfur. This analysis shall be made from a test ingot taken during the pouring of the heat. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements for heat analysis in accordance with Table 1.

5.3 Product Analysis—An analysis may be made by the purchaser from finished materials representing each heat. The chemical composition thus determined shall conform to the requirements for product analysis prescribed in Table 1.

*A Summary of Changes section appears at the end of this standard.

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5.4 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

5.5 Chemical analyses shall be performed in accordance with Test Methods A 751.

6. Mechanical Properties

6.1 Rivet Bend Tests:

6.1.1 The rivet shank of Grade A steel shall stand being bent cold through 180° flat on itself, as shown in Fig. 1, without cracking on the outside of the bent portion.

6.1.2 The rivet shank of Grade B steel shall stand being bent cold through 180° without cracking on the outside of the bent portion in accordance with Table 2.

6.2 Rivet Flattening Tests—The rivet head shall stand being flattened, while hot, to a diameter 2½ times the diameter of the shank, as shown in Fig. 2, without cracking at the edges.

6.3 Bar Tensile Properties—Bars shall conform to the tensile requirements in accordance with Table 3.

6.4 Bar Bend Tests:

6.4.1 The test specimen for Grade A steel bars shall stand being bent cold through 180° flat on itself without cracking on the outside of the bent portion.

6.4.2 The test specimen for Grade B steel bars shall stand being bent cold through 180° without cracking on the outside of the bent portion to an inside diameter which shall have a relation to the diameter of the specimen in accordance with Table 4.

7. Dimensions, Mass, and Permissible Variations

7.1 Rivets:

7.1.1 The dimensions of rivets shall conform to ANSI B18.1.2 for nominal diameters in. and larger and B18.1.1 for nominal diameters 3/16 in. and less.

7.1.2 Snap gage measurement shall be made at the point of minimum diameter, but it is not required that the rivet shall turn completely in the gage. Measurements of the maximum tolerances shall be made with a ring gage, all rivets to slip full to the head in the gage of the required size for the various diameters.

7.2 Bars—The diameter of hot-finished rivet bars shall not vary from the size specified by more than the amounts in accordance with Table 5.

8. Workmanship, Finish, and Appearance

8.1 Rivets—The finished rivets shall be true to form, concentric, and free of injurious defects.

### TABLE 1 Chemical Requirements

<table>
<thead>
<tr>
<th></th>
<th>Grade A</th>
<th>Grade B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heat Analysis</td>
<td>Product Analysis</td>
</tr>
<tr>
<td>Carbon, max, %</td>
<td>. . .</td>
<td>. . .</td>
</tr>
<tr>
<td>Manganese, %</td>
<td>0.30–0.60</td>
<td>0.27–0.63</td>
</tr>
<tr>
<td>Phosphorus, max, %</td>
<td>0.040</td>
<td>0.048</td>
</tr>
<tr>
<td>Sulfur, max, %</td>
<td>0.050</td>
<td>0.058</td>
</tr>
</tbody>
</table>

### TABLE 2 Bend Requirements, Rivets

<table>
<thead>
<tr>
<th>Diameter of Rivet Shank, in.</th>
<th>Grade A</th>
<th>Grade B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of Bend Diameter to Diameter of River Shank</td>
<td></td>
<td></td>
</tr>
<tr>
<td>¾ and under</td>
<td>flat</td>
<td>1</td>
</tr>
<tr>
<td>Over ¾</td>
<td>flat</td>
<td>1½</td>
</tr>
</tbody>
</table>

### TABLE 3 Tensile Requirements, Bars

<table>
<thead>
<tr>
<th>Grade A</th>
<th>Grade B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength, psi (MPa)</td>
<td>45 000–55 000 (310–380)</td>
</tr>
<tr>
<td>Yield point, min, psi (MPA)</td>
<td>23 000 (160)</td>
</tr>
<tr>
<td>Elongation in 8 in. or 200 mm, min, %</td>
<td>27</td>
</tr>
<tr>
<td>Elongation in 2 in. or 50 mm, min, %</td>
<td>33</td>
</tr>
</tbody>
</table>

### TABLE 4 Bend Requirements, Bars

<table>
<thead>
<tr>
<th>Specimen Diameter, in.</th>
<th>Grade A</th>
<th>Grade B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of Bend Diameter to Diameter of Specimen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>¾ and under</td>
<td>flat</td>
<td>1½</td>
</tr>
<tr>
<td>Over ¾</td>
<td>flat</td>
<td>1</td>
</tr>
</tbody>
</table>

### TABLE 5 Permissible Variations in the Size of Hot-Rolled Rounds

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Over</td>
<td>Under</td>
</tr>
<tr>
<td>¾ and under</td>
<td>0.005</td>
<td>0.005</td>
</tr>
<tr>
<td>Over ¾ to ¾, incl</td>
<td>0.006</td>
<td>0.006</td>
</tr>
<tr>
<td>Over ¾ to ½, incl</td>
<td>0.007</td>
<td>0.007</td>
</tr>
<tr>
<td>Over ½ to ½, incl</td>
<td>0.008</td>
<td>0.008</td>
</tr>
<tr>
<td>Over ½ to 1, incl</td>
<td>0.009</td>
<td>0.009</td>
</tr>
<tr>
<td>Over 1 to 1¼, incl</td>
<td>0.010</td>
<td>0.010</td>
</tr>
<tr>
<td>Over 1¼ to 1½, incl</td>
<td>0.011</td>
<td>0.011</td>
</tr>
<tr>
<td>Over 1½ to 1¾, incl</td>
<td>0.012</td>
<td>0.012</td>
</tr>
<tr>
<td>Over 1¾ to 1½, incl</td>
<td>0.014</td>
<td>0.014</td>
</tr>
</tbody>
</table>

* A Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same cross section.
8.2 **Bars:**

8.2.1 Bars shall be free of visible pipe, undue segregation, and injurious surface imperfections.

8.2.2 **Surface Finish**—The bars shall have a commercial hot-worked finish obtained by conventional hot rolling. See 4.4 for producer’s descaling option.

9. **Number of Tests and Retests**

9.1 **Rivets**—Sampling for rivet bend and rivet flattening tests shall be in accordance with Guide F 1470, detection process.

9.2 **Bars:**

9.2.1 Two tension tests shall be made from each heat, unless the finished material from a heat is less than 50 tons (45 Mg), when one tension test will be sufficient. However, for material 2 in. (51 mm) and under in thickness, when the material from one heat differs 3/8 in. (9.5 mm) or more in thickness, one tension test shall be made from both the thickest and the thinnest material rolled regardless of the weight represented. Each test shall conform to the specified requirements.

9.2.2 Retests on bars may be made in accordance with Specification A 29/A 29M.

10. **Specimen Preparation**

10.1 **Rivets**—Rivets shall be tested in their full-size finished condition.

10.2 **Bars:**

10.2.1 Test specimen selection and preparation shall be in accordance with Specification A 29/A 29M and Test Methods A 370.

10.2.2 Tension and bend test specimens for rivet bars which have been cold drawn shall be normalized before testing.

11. **Test Methods**

11.1 **Rivets**—Rivet bend and flattening tests shall be in accordance with the manufacturers standard test procedures.

11.2 **Bars**—Tension and bend tests shall be conducted in accordance with Test Methods A 370, and especially Supplement I thereof, on steel bar products.

12. **Inspection**

12.1 If the testing described in Section 9 is required by the purchaser, it shall be specified in the inquiry and contract or order.

12.2 The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities, without charge, to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

13. **Rejection and Rehearing**

13.1 **Rivets**—Rivets that fail to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

13.2 **Bars**—Rejection and rehearing shall be in accordance with Specification A 29/A 29M.

14. **Certification**

14.1 When specified on the purchase order, the manufacturer shall furnish certification that the material was manufactured and tested in accordance with this specification together with a report of the heat analysis (5.2) and mechanical property test results (Section 6) as applicable to the product ordered. The report shall include the manufacturer’s name, ASTM designation, grade, heat number (bars only), and authorized signature.

15. **Responsibility**

15.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested, and inspected in accordance with this specification and meets all of its requirements.

16. **Packaging and Package Marking**

16.1 **Rivets**—Rivets shall be properly packed and marked to prevent damage and loss during shipment.

16.2 **Bars**—Bars shall be packed and marked in accordance with Specification A 29/A 29M.

17. **Keywords**

17.1 bars; carbon steel; pressure vessel rivets; rivets; steel
SUMMARY OF CHANGES

This section identifies the location of selected changes to this specification that have been incorporated since the –95 issue. For the convenience of the user, Committee F16 has highlighted those changes that may impact the use of this specification. This section may also include descriptions of the changes or reasons for the changes, or both.


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Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength

This standard is issued under the fixed designation A 307; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers the chemical and mechanical requirements of three grades of carbon steel bolts and studs in sizes \( \frac{1}{4} \) in. (6.35 mm) through 4 in. (104 mm). The fasteners are designated by “Grade” denoting tensile strength and intended use, as follows:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade A</td>
<td>Bolts and studs having a minimum tensile strength of 60 ksi (414 MPa) and intended for general applications,</td>
</tr>
<tr>
<td>Grade B</td>
<td>Bolts and studs having a tensile strength of 60 to 100 ksi (414 to 690 MPa) and intended for flanged joints in piping systems with cast iron flanges, and</td>
</tr>
<tr>
<td>Grade C</td>
<td>Nonheaded anchor bolts, either bent or straight, having properties conforming to Specification A 96 (tensile strength of 58 to 80 ksi (400 to 550 MPa)) and intended for structural anchorage purposes.</td>
</tr>
</tbody>
</table>

1.1.1 The term studs includes stud stock, sometimes referred to as threaded rod.

1.2 This specification does not cover requirements for machine screws, thread cutting/forming screws, mechanical expansion anchors or similar externally threaded fasteners.

1.3 Suitable nuts are covered in Specification A 563. Unless otherwise specified, the grade and style of nut for each grade of fastener, of all surface finishes, shall be as follows:

<table>
<thead>
<tr>
<th>Fastener Grade and Size</th>
<th>Nut Grade and StyleA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, C, ¼ to 1½ in.</td>
<td>A, hex</td>
</tr>
<tr>
<td>A, C, over 1½ to 4 in.</td>
<td>A, heavy hex</td>
</tr>
<tr>
<td>B, ¼ to 4 in.</td>
<td>A, heavy hex</td>
</tr>
</tbody>
</table>

A Nuts of other grades and styles having specified proof load stresses (Specification A 563, Table 3) greater than the specified grade and style of nut are also suitable.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 Supplementary Requirement S1 of an optional nature is provided, which describes additional restrictions to be applied when bolts are to be welded. It shall apply only when specified in the inquiry, order, and contract.

1.6 Terms used in this specification are defined in Specification F 1789 unless otherwise defined herein.

2. Referenced Documents

2.1 ASTM Standards:
A 36/A 36M Specification for Carbon Structural Steel
A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 563 Specification for Carbon and Alloy Steel Nuts
A 706/A 706M Specification for Low-Alloy Steel Deformed Bars for Concrete Reinforcement
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
D 3951 Practice for Commercial Packaging
F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
F 1789 Terminology for F16 Mechanical Fasteners

2.2 ANSI/ASME Standards:
B 1.1 Unified Screw Threads

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3 This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.02 on Steel Bolts, Nuts, Rivets, and Washers.


*For ASME Boiler and Pressure Vessel Code applications see related Specification SA-307 in Section II of that Code.

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*Annual Book of ASTM Standards, Vol 01.06.
*Annual Book of ASTM Standards, Vol 01.03.
*Annual Book of ASTM Standards, Vol 01.08.
*Annual Book of ASTM Standards, Vol 02.05.

* A Summary of Changes section appears at the end of this standard.
3. Ordering Information

3.1 Orders for externally threaded fasteners (including nuts and accessories) under this specification shall include the following:

3.1.1 ASTM designation and year of issue,

3.1.2 Name of product, bolts or studs; and bolt head style, that is, hex or heavy hex,

3.1.3 Grade, that is, A, or B, or C. If no grade is specified, Grade A is furnished.

3.1.4 Quantities (number of pieces by size including nuts),

3.1.5 Fastener size and length,

3.1.6 Washers—Quantity and size (separate from bolts),

3.1.7 Zinc Coating—Specify the zinc-coating process required, for example, hot-dip, mechanically deposited, or no preference (see 4.5).

3.1.8 Other Finishes—Specify other protective finish, if required.

3.1.9 Specify if inspection at point of manufacture is required,

3.1.10 Specify if certified test report is required (see 8.2), and

3.1.11 Specify additional testing (8.3) or special requirements.

3.1.12 For establishment of a part identifying system, see ANSI/ASME B18.24.1.

4. Materials and Manufacture

4.1 Steel for bolts and studs shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

4.2 Bolts shall be produced by hot or cold forging of the heads or machining from bar stock.

4.3 Heat Treatment:

4.3.1 Cold headed fasteners with head configurations other than hex shall be stress relief annealed.

4.3.2 Stress relieving of hex head fasteners shall be at the manufacturer’s option.

4.4 Bolt and stud threads shall be rolled or cut.

4.5 Zinc Coatings, Hot-Dip and Mechanically Deposited:

4.5.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc-coating process, for example hot dip, mechanically deposited, or no preference.

4.5.2 When hot-dip is specified, the fasteners shall be zinc-coated by the hot-dip process in accordance with the requirements of Class C of Specification B 695.

4.5.3 When mechanically deposited is specified, the fasteners shall be zinc-coated by the mechanical-deposition process in accordance with the requirements of Class C of Specification B 695.

4.5.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification A 153, Class C or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process and the supplier’s option is limited to one process per item with no mixed processes in a lot.

5. Chemical Composition

5.1 Grade A and B bolts and studs shall have a heat analysis conforming to the requirements specified in Table 1 based on the steel producer’s heat analysis.

5.2 The purchaser shall have the option of conducting product analyses on finished bolts in each lot, which shall conform to the product analysis specified in Table 1.

5.3 In case of conflict or for referee purposes, the product analysis shall take precedence.

5.4 Bolts and studs are customarily furnished from stock, in which case individual heats of steel cannot be identified.

5.5 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for Grade B bolts and studs.

5.6 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 Grades A and B bolts and studs shall conform to the hardness specified in Table 2.

6.2 Grade A and B bolts and studs 1½ in. in diameter or less, other than those excepted in 6.4, shall be tested full size and shall conform to the requirements for tensile strength specified in Table 3.

6.3 Grade A and B bolts and studs larger than 1½ in. in diameter, other than those excepted in 6.4, shall preferably be tested full size and when equipment of sufficient capacity is available and shall conform to the requirements for tensile strength specified in Table 3. When equipment of sufficient capacity for full-size bolt testing is not available, or when the length of the bolt makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements specified in Table 4.

6.4 Grades A and B bolts and studs less than three diameters in length or bolts with drilled or undersize heads are not subject to tensile tests.

6.5 Grade C nonheaded anchor bolts shall be tested using machined specimens and shall conform to the tensile properties specified for bars in Specification A 36/A 36M. Properties are

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**TABLE 1 Chemical Requirements for Grades A and B Bolts and Studs**

<table>
<thead>
<tr>
<th>Component</th>
<th>Heat Analysis</th>
<th>Product Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon, max</td>
<td>0.29</td>
<td>0.33</td>
</tr>
<tr>
<td>Manganese, max</td>
<td>0.90</td>
<td>0.93</td>
</tr>
<tr>
<td>Phosphorous, max</td>
<td>0.04</td>
<td>0.041</td>
</tr>
<tr>
<td>Sulfur, max</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade A</td>
<td>0.15</td>
<td>^</td>
</tr>
<tr>
<td>Grade B</td>
<td>0.05</td>
<td>0.051</td>
</tr>
</tbody>
</table>

^ Resulfurized steel is not subject to rejection based on product analysis for sulfur.
shown in Table 4 for information. In the event of conflict Specification A 36/A 36M shall control.

6.6 In the event that bolts are tested by both full size and by machine test specimen methods, the full-size test shall govern if a controversy between the two methods exists.

6.7 For bolts and studs on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event that there is controversy over low readings of hardness tests.

7. Dimensions

7.1 Unless otherwise specified, threads shall be the Coarse Thread Series as specified in the latest issue of ANSI/ASME B1.1, and shall have a Class 2A tolerance.

7.2 Unless otherwise specified, Grade A bolts shall be hex bolts with dimensions as given in the latest issue of ANSI/ASME B18.2.1. Unless otherwise specified, Grade B bolts shall be heavy hex bolts with dimensions as given in the latest issue of ANSI/ASME B18.2.1.

7.3 Unless otherwise specified, bolts and studs to be used with nuts or tapped holes which have been tapped oversize, in accordance with Specification A 563, shall have Class 2A threads before hot-dip or mechanically deposited zinc coating. After zinc coating the maximum limit of pitch and major diameter shall not exceed the Class 2A maximum limit by more than the following amounts:

<table>
<thead>
<tr>
<th>Diameter, in.</th>
<th>Oversize Limit, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4</td>
<td>0.016</td>
</tr>
<tr>
<td>5/32, 3/8</td>
<td>0.017</td>
</tr>
<tr>
<td>7/32, 1/2</td>
<td>0.018</td>
</tr>
<tr>
<td>9/32 to 3/4, incl</td>
<td>0.020</td>
</tr>
<tr>
<td>7/8</td>
<td>0.022</td>
</tr>
<tr>
<td>1 to 11/4, incl</td>
<td>0.024</td>
</tr>
<tr>
<td>11/16, 5/8</td>
<td>0.027</td>
</tr>
<tr>
<td>13/16 to 4, incl</td>
<td>0.050</td>
</tr>
</tbody>
</table>

A These values are the same as the overtapping required for zinc-coated nuts in Specification A 563.

7.4 The gaging limit for bolts and studs shall be verified during manufacture or use by assembly of a nut tapped as nearly as practical to the amount oversize shown above. In case of dispute, a calibrated thread ring gage of that same size (Class X tolerance, gage tolerance plus) shall be used. Assembly of the gage, or the nut described above, must be possible with hand effort following application of light machine oil to prevent galling and damage to the gage. These inspections, when performed to resolve disputes, shall be performed at the frequency and quality described in Table 5.

### Table 2 Hardness Requirements for Bolts and Studs

<table>
<thead>
<tr>
<th>Grade</th>
<th>Length, in.</th>
<th>Hardness&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>Brinell</td>
</tr>
<tr>
<td></td>
<td></td>
<td>min</td>
</tr>
<tr>
<td>A</td>
<td>Less than 3 x dia&lt;sup&gt;b&lt;/sup&gt;</td>
<td>121</td>
</tr>
<tr>
<td>A</td>
<td>3 x dia and longer</td>
<td>241</td>
</tr>
<tr>
<td>B</td>
<td>Less than 3 x dia&lt;sup&gt;b&lt;/sup&gt;</td>
<td>121</td>
</tr>
<tr>
<td>B</td>
<td>3 x dia and longer</td>
<td>...</td>
</tr>
<tr>
<td>C</td>
<td>All</td>
<td>No hardness required</td>
</tr>
</tbody>
</table>

<sup>a</sup> As measured anywhere on the surface or through the cross section.

<sup>b</sup> Also bolts with drilled or undersize heads. These sizes and bolts with modified heads shall meet the minimum and maximum hardness as hardness is the only requirement.

### Table 3 Tensile Requirements for Full-Size Bolts and Studs

<table>
<thead>
<tr>
<th>Bolt Size, in.</th>
<th>Threads per inch</th>
<th>Stress Area, A&lt;sup&gt;c&lt;/sup&gt; in.²</th>
<th>Tensile Strength, lbf&lt;sup&gt;d&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4</td>
<td>20</td>
<td>0.0318</td>
<td>Grade A, min B</td>
</tr>
<tr>
<td>5/32, 3/8</td>
<td>18</td>
<td>0.0524</td>
<td>Grade B, min D max D</td>
</tr>
<tr>
<td>7/32, 1/2</td>
<td>16</td>
<td>0.0775</td>
<td></td>
</tr>
<tr>
<td>9/32 to 3/4, incl</td>
<td>14</td>
<td>0.1063</td>
<td></td>
</tr>
<tr>
<td>7/8</td>
<td>12</td>
<td>0.1419</td>
<td></td>
</tr>
<tr>
<td>11/16, 5/8</td>
<td>10</td>
<td>0.182</td>
<td></td>
</tr>
<tr>
<td>13/16 to 4, incl</td>
<td>9</td>
<td>0.242</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>8</td>
<td>0.606</td>
<td></td>
</tr>
<tr>
<td>1 1/4</td>
<td>7</td>
<td>0.763</td>
<td></td>
</tr>
<tr>
<td>1 1/2</td>
<td>6</td>
<td>1.155</td>
<td></td>
</tr>
<tr>
<td>1 1/4</td>
<td>6</td>
<td>1.405</td>
<td></td>
</tr>
<tr>
<td>1 3/4</td>
<td>5</td>
<td>1.90</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4 1/2</td>
<td>2.50</td>
<td></td>
</tr>
<tr>
<td>2 1/4</td>
<td>4 1/2</td>
<td>3.25</td>
<td></td>
</tr>
<tr>
<td>2 3/4</td>
<td>4</td>
<td>4.00</td>
<td></td>
</tr>
<tr>
<td>2 1/2</td>
<td>4</td>
<td>4.93</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>5.97</td>
<td></td>
</tr>
<tr>
<td>3 1/4</td>
<td>4</td>
<td>7.10</td>
<td></td>
</tr>
<tr>
<td>3 3/4</td>
<td>4</td>
<td>8.33</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>9.66</td>
<td></td>
</tr>
<tr>
<td>4 1/2</td>
<td>4</td>
<td>11.08</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Area calculated from the equation:

\[ A_s = 0.7854 \left[ D - \left(0.9743/n\right) \right]^2 \]

where:

\[ A_s = \] stress area,
\[ D = \] nominal diameter of bolt, and
\[ n = \] threads per inch.

<sup>b</sup> As measured anywhere on the surface or through the cross section.

<sup>c</sup> Also bolts with drilled or undersize heads. These sizes and bolts with modified heads shall meet the minimum and maximum hardness as hardness is the only requirement.

<sup>d</sup> Based on 60 ksi (414 MPa).

<sup>e</sup> Based on 60–100 ksi (414–690 MPa).

### Table 4 Tensile Requirements for Machined Specimens

<table>
<thead>
<tr>
<th>Grade</th>
<th>Tensile strength, ksi</th>
<th>Yield point, min ksi</th>
<th>Elongation in 2 in., min, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>60 min</td>
<td>...</td>
<td>18</td>
</tr>
<tr>
<td>B</td>
<td>60–100</td>
<td>...</td>
<td>18</td>
</tr>
<tr>
<td>C</td>
<td>58–80</td>
<td>...</td>
<td>23</td>
</tr>
</tbody>
</table>

### Table 5 Sample Sizes and Acceptance Numbers for Inspection of Hot-Dip or Mechanically Deposited Zinc-Coated Threads

<table>
<thead>
<tr>
<th>Lot Size</th>
<th>Sample Size&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Acceptance Number&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 90</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>91 to 150</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>151 to 280</td>
<td>32</td>
<td>3</td>
</tr>
<tr>
<td>281 to 500</td>
<td>50</td>
<td>5</td>
</tr>
<tr>
<td>501 to 1 200</td>
<td>80</td>
<td>7</td>
</tr>
<tr>
<td>1 201 to 3 200</td>
<td>125</td>
<td>10</td>
</tr>
<tr>
<td>3 201 to 10 000</td>
<td>200</td>
<td>14</td>
</tr>
<tr>
<td>10 001 and over</td>
<td>315</td>
<td>21</td>
</tr>
</tbody>
</table>

<sup>a</sup> Sample sizes of acceptance numbers are extracted from “Single Sampling Plan for Normal Inspection,” Table II A, MIL-STD-105.

<sup>b</sup> Inspect all bolts in the lot if the lot size is less than the sample size.
8. Number of Tests and Retests

8.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated. Individual heats of steel are not identified in the finished product.

8.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last completed set of mechanical tests for each stock size in each shipment.

8.3 When additional tests are specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all material offered for inspection at one time that has the following common characteristics:

8.3.1 One type of item,
8.3.2 One nominal size, and
8.3.3 One nominal length of bolts and studs.

8.4 From each lot, the number of tests for each requirement shall be as follows:

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and under</td>
<td>1</td>
</tr>
<tr>
<td>801 to 8 000</td>
<td>2</td>
</tr>
<tr>
<td>8 001 to 22 000</td>
<td>3</td>
</tr>
<tr>
<td>Over 22 000</td>
<td>5</td>
</tr>
</tbody>
</table>

8.5 If any machined test specimen shows defective machining it shall be discarded and another specimen substituted.

8.6 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be tested, in which case all of the additional samples shall meet the specification.

9. Test Methods

9.1 Grades A and B bolts and studs shall be tested in accordance with Test Methods F 606.

9.2 Grade C nonheaded anchor bolts shall have machined specimen tension tests made on the bolt body or on the bar stock used for making the anchor bolts. Tests on finished anchor bolts shall be made in accordance with Test Methods F 606 and tests on bar stock in accordance with Specification A 36/A 36M and Test Methods A 370.

9.3 Standard square and hex head bolts only shall be tested by the wedge tension method except as noted in 6.4. Fracture shall be in the body or threads of the bolt without any fracture at the junction of the head and body. Other headed bolts shall be tested by the axial tension method.

9.4 Speed of testing as determined with a free running crosshead shall be a maximum of 1 in. (25.4 mm)/min for the tensile strength tests of bolts.

10. Inspection

10.1 If the inspection described in 10.2 is required by the purchaser it shall be specified in the inquiry, order, or contract.

10.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser’s representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

11. Responsibility

11.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

12. Rejection and Rehearing

12.1 Disposition of nonconforming lots shall be in accordance with Guide F 1470, specifically sections on disposition of nonconforming lots, suppliers option, and purchasers option.

13. Product Marking

13.1 Grades A and B Bolts and Studs:
13.1.1 Bolt heads and one end of studs shall be marked with a unique identifier by the manufacturer to identify the manufacturer or private label distributor, as appropriate. Additional marking required by the manufacturer for his own use shall be at the option of the manufacturer.

13.1.2 In addition to the requirements of 13.1, all bolt heads, one end of studs ½ in. and larger, and whenever feasible studs less than ½ in. shall be marked with a grade marking as follows:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>307A</td>
</tr>
<tr>
<td>B</td>
<td>307B</td>
</tr>
</tbody>
</table>

13.1.3 All markings shall be located on the top of the bolt head or stud end and shall be raised or depressed at the option of the manufacturer.

13.2 Grade C Anchor Bolts:
13.2.1 The end of Grade C anchor bolts intended to project from the concrete shall be color coded green.

13.2.2 When permanent marking of manufacturer’s identification and grade identification is required, Supplementary Requirements S2 and S3 shall be specified.

13.3 Grade and manufacturer’s or private label distributor’s identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

14. Packaging and Package Marking

14.1 Packaging:
14.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

14.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

14.2 Package Marking:

14.2.1 Each shipping unit shall include or be plainly marked with the following information:

<table>
<thead>
<tr>
<th>Information</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM designation and grade</td>
<td>A307B</td>
</tr>
<tr>
<td>Size</td>
<td></td>
</tr>
<tr>
<td>Name and brand or trademark of the manufacturer</td>
<td></td>
</tr>
<tr>
<td>Number of pieces</td>
<td></td>
</tr>
<tr>
<td>Purchase order number</td>
<td></td>
</tr>
<tr>
<td>Country of origin</td>
<td></td>
</tr>
</tbody>
</table>
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified in the purchase order or contract:

S1. Bolts Suitable for Welding

S1.1 The material described in this section is intended for welding. This supplemental section, by additional chemical composition restrictions and by a carbon equivalent formula, provides assurance of weldability by chemical composition control.

S1.2 Welding technique is of fundamental importance when bolts produced to this supplementary section are welded. It is presupposed that suitable welding procedures for the steel being welded and the intended service will be selected.

S1.3 All of the requirements of this supplemental section apply in addition to all of the chemical, mechanical, and other requirements of the base specification, Specification A 307 for Grade B.

S1.4 Because of the embrittling effects of welding temperatures on cold-forged steel, this supplemental section is limited to hot-forged bolts, or, if not forged, then to bolts produced from hot-rolled bars without forging or threaded bars, bars studs, or stud bolts produced from hot-rolled bars without forging. Cold-forged bolts, or cold-drawn threaded bars, if they are given a thermal treatment by heating to a temperature of not less than 1500°F (815°C) and air-cooled are also suitable.

S1.5 Chemical Requirements:

S1.5.1 Heat Chemical Analysis—Material conforming to the following additional analysis limitations shall be used to manufacture the product described in this supplementary requirement.

<table>
<thead>
<tr>
<th>Element</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>0.30%, max</td>
</tr>
<tr>
<td>Manganese</td>
<td>1.00%, max</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.04%, max</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.05%, max</td>
</tr>
<tr>
<td>Silicon</td>
<td>0.50%, max</td>
</tr>
</tbody>
</table>

S1.5.2 Carbon Equivalent (Source—Specification A 706/A 706M)—In addition to the heat chemical analysis requirements in S1.5.1, the heat analysis shall be such as to provide a carbon equivalent (CE) not exceeding 0.55 when calculated as follows:

\[
CE = \%C + \frac{\%Mn}{6} + \frac{\%Cu}{40} + \frac{\%Ni}{20} + \frac{\%Cr}{10} - \frac{\%Mo}{50} - \frac{\%V}{10}
\]

S1.6 Analysis Reports—If requested on the order or contract, the chemical composition of each heat of steel used and the calculated carbon equivalent for each heat shall be reported to the purchaser.

S1.7 Product (Check) Verification Analysis—Chemical analyses when made by the purchaser or a representative on bolts from each heat of steel, shall not exceed the values specified in S1.5.2 by more than the following amounts:

<table>
<thead>
<tr>
<th>Element</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>+0.03</td>
</tr>
<tr>
<td>Manganese</td>
<td>+0.06</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>+0.008</td>
</tr>
<tr>
<td>Sulfur</td>
<td>+0.008</td>
</tr>
<tr>
<td>Silicon</td>
<td>+0.05</td>
</tr>
</tbody>
</table>

S2. Permanent Manufacturer’s Identification

S2.1 The end of the anchor bolt intended to project from the concrete shall be steel die stamped with the manufacturer’s identification.

Note: For marking small sizes, customarily less than 3/8 in., consult the anchor bolt manufacturer for the minimum size capable of being marked.

S3. Permanent Grade Identification

S3.1 The end of the anchor bolt intended to project from the concrete shall be steel die stamped with the Grade identification “307C”.

S3.2 The requirements in S2.1 for marking small sizes shall also apply to Supplementary Requirement S3.
SUMMARY OF CHANGES

This section identifies the location of selected changes to this standard that have been incorporated since the A 307 – 02 issue. For the convenience of the user, Committee F16 has highlighted those changes that impact the use of this standard. This section may also include descriptions of the changes or reasons for the changes, or both. (Approved Oct. 1, 2003.)

(1) Added Section 1.6 that references Terminology F 1789 for definitions of terms.

(2) Deleted the metric units from Table 4.

(2) Corrected the carbon equivalent formula for nickel in S1.5.2.

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Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength

This standard is issued under the fixed designation A 325; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers two types of quenched and tempered steel heavy hex structural bolts having a minimum tensile strength of 120 ksi for sizes 1.0 in. and less and 105 ksi for sizes over 1.0 to 1½ in., inclusive.

1.2 The bolts are intended for use in structural connections. These connections are covered under the requirements of the Specification for Structural Joints Using ASTM A 325 or A 490 Bolts, approved by the Research Council on Structural Connections, endorsed by the American Institute of Steel Construction and by the Industrial Fastener Institute.

1.3 The bolts are furnished in sizes ½ to 1½ in., inclusive. They are designated by type, denoting chemical composition as follows:

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>Medium carbon, carbon boron, or medium carbon alloy steel.</td>
</tr>
<tr>
<td>Type 2</td>
<td>Withdrawn in November 1991.</td>
</tr>
<tr>
<td>Type 3</td>
<td>Weathering steel.</td>
</tr>
</tbody>
</table>

Note 1—Bolts for general applications, including anchor bolts, are covered by Specification A 449. Also refer to Specification A 449 for quenched and tempered steel bolts and studs with diameters greater than 1½ in. but with similar mechanical properties.

Note 2—A complete metric companion to Specification A 325 has been developed—Specification A 325M; therefore, no metric equivalents are presented in this specification.

1.4 This specification is applicable to heavy hex structural bolts only. For bolts of other configurations and thread lengths with similar mechanical properties, see Specification A 449.

1.5 Terms used in this specification are defined in Specification F 1789.

1.6 The following safety hazards caveat pertains only to the test methods portion, Section 10, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
A 449 Specification for Quenched and Tempered Steel Bolts and Studs
A 490 Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength
A 563 Specification for Carbon and Alloy Steel Nuts
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
D 3951 Practice for Commercial Packaging
F 436 Specification for Hardened Steel Washers
F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
F 788/F 788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series
F 959 Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners
F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
F 1789 Terminology for F16 Mechanical Fasteners


2 For ASME Boiler and Pressure Vessel Code applications see related Specification SA-325 in Section II of that Code.

3 Published by American Institute of Steel Construction, One East Wacker Dr., Ste. 3100, Chicago, IL 60601-2001.

* A Summary of Changes section appears at the end of this standard.

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2.2 ASME Standards:5
B 1.1 Unified Screw Threads
B 18.2.6 Fasteners for Use in Structural Applications
B 18.24.1 Part Identifying Number (PIN) Code System
2.3 MIL-STD-105 Sampling Procedure and Tables for Inspection by Attributes

3. Ordering Information

3.1 Orders for heavy hex structural bolts under this specification shall include the following:
3.1.1 Quantity (number of pieces of bolts and accessories).
3.1.2 Size, including nominal bolt diameter, thread pitch, and bolt length.
3.1.3 Name of product, heavy hex structural bolts.
3.1.4 When bolts threaded full length are required, Supplementary Requirement S1 shall be specified.
3.1.5 Type of bolt: Type 1 or 3. When type is not specified, either Type 1 or Type 3 shall be furnished at the supplier’s option.
3.1.6 ASTM designation and year of issue.
3.1.7 Other components such as nuts, washers, and compressible washer-type direct-tension indicators, if required.
3.1.7.1 When such other components are specified to be furnished, also state “Nuts, washers, and direct tension indicators, or combination thereof, shall be furnished by lot number.”
3.1.8 Zinc Coating—Specify the zinc coating process required, for example, hot dip, mechanically deposited, or no preference (see 4.3).
3.1.9 Other Finishes—Specify other protective finish, if required.
3.1.10 Test reports, if required (see Section 13).
3.1.11 Supplementary or special requirements, if required.
3.1.12 For establishment of a part identifying system, see ASME B18.24.1.

NOTE 3—A typical ordering description follows: 1000 pieces 1\&-7 UNC in. dia \(\times\) 4 in. long heavy hex structural bolt, Type 1 ASTM A 325–02, each with one hardened washer, ASTM F 436 Type 1, and one heavy hex nut, ASTM A 563 Grade DH. Each component hot-dip zinc-coated. Nuts lubricated.

3.2 Recommended Nuts:

3.2.1 Nuts conforming to the requirements of Specification A 563 are the recommended nuts for use with Specification A 325 heavy hex structural bolts. The nuts shall be of the class and have a surface finish for each type of bolt as follows:

Bolt Type and Finish

Nut Class and Finish

| 1. plain (noncoated) | A 563-C, C 3, D, DH, DH3, plain |
| 1. zinc coated | A 563-DH, zinc coated |
| 3. plain | A 563-C3, DH3, plain |

3.2.2 Alternatively, nuts conforming to Specification A 194/A 194M Gr. 2H are considered a suitable substitute for use with Specification A 325 Type 1 heavy hex structural bolts.

3.2.3 When Specification A 194/A 194M Gr. 2H zinc-coated nuts are supplied, the zinc coating, overtapping, lubrication, and rotational capacity testing shall be in accordance with Specification A 563.

3.3 Recommended Washers:

3.3.1 Washers conforming to Specification F 436 are the recommended washers for use with Specification A 325 heavy hex structural bolts. The washers shall have a surface finish for each type of bolt as follows:

| Bolt Type and Finish | Washer Finish |
| Bolt Type and Finish | Washer Finish |
| 1. plain (uncoated) | plain (uncoated) |
| 1. zinc coated | zinc coated |
| 3. plain | weathering steel, plain |

3.4 Other Accessories:

3.4.1 When compressible washer type direct tension indicators are specified to be used with these bolts, they shall conform to Specification F 959 Type 325.

4. Materials and Manufacture

4.1 Heat Treatment:

4.1.1 Type 1 bolts produced from medium carbon steel shall be quenched in a liquid medium from the austenitizing temperature. Type 1 bolts produced from medium carbon steel to which chromium, nickel, molybdenum, or born were intentionally added shall be quenched only in oil from the austenitizing temperature.

4.1.2 Type 3 bolts shall be quenched only in oil from the austenitizing temperature.

4.1.3 Type 1 bolts, regardless of the steel used, and Type 3 bolts shall be tempered by reheating to not less than 800°F.

4.2 Threading—Threads shall be cut or rolled.

4.3 Zinc Coatings, Hot-Dip and Mechanically Deposited:

4.3.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc coating process, for example, hot dip, mechanically deposited, or no preference.

4.3.2 When hot-dip is specified, the fasteners shall be zinc-coated by the hot-dip process and the coating shall conform to the coating weight/thickness and performance requirements of Class C of Specification A 153.

4.3.3 When mechanically deposited is specified, the fasteners shall be zinc-coated by the mechanical deposition process and the coating shall conform to the coating weight/thickness and performance requirements of Class 50 of Specification B 695.

4.3.4 When no preference is specified, the supplier shall furnish either a hot-dip zinc coating in accordance with Specification A 153, Class C, or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process and the supplier’s option is limited to one process per item with no mixed processes in a lot.

4.4 Lubrication—When zinc-coated nuts are ordered with the bolts, the nuts shall be lubricated in accordance with Specification A 563, Supplementary Requirement S1, to minimize galling.

4.5 Secondary Processing:
4.5.1 If any processing, which can affect the mechanical properties or performance of the bolts, is performed after the initial testing, the bolts shall be retested for all specified mechanical properties and performance requirements affected by the reprocessing.

4.5.2 When the secondary process is heat treatment, the bolts shall be tested for all specified mechanical properties. Hot dip zinc-coated bolts shall be tested for all specified mechanical properties and rotational capacity. If zinc-coated nuts are relubricated after the initial rotational capacity tests, the assemblies shall be retested for rotational capacity.

5. Chemical Composition

5.1 Type 1 bolts shall be plain carbon steel, carbon boron steel, alloy steel or alloy boron steel at the manufacturer’s option, conforming to the chemical composition specified in Table 1.

5.2 Type 3 bolts shall be weathering steel and shall conform to one of the chemical compositions specified in Table 2. The selection of the chemical composition, A, B, C, D, E, or F, shall be at the option of the bolt manufacturer. See Guide G 101 for methods of estimating the atmospheric corrosion resistance of low alloy steels.

5.3 Product analyses made on finished bolts representing each lot shall conform to the product analysis requirements specified in Table 1 and Table 2, as applicable.

5.4 Heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for bolts.

5.5 Compliance with 5.4 shall be based on certification that heats of steel having any of the listed elements intentionally added were not used to produce the bolts.

5.6 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 Hardness—The bolts shall conform to the hardness specified in Table 3.

6.2 Tensile Properties:

6.2.1 Except as permitted in 6.2.2 for long bolts and 6.2.3 for short bolts, sizes 1.00 in. and smaller having a length of 2½ D and longer, and sizes larger than 1.00 in. having a length of 3D and longer, shall be wedge tested full size and shall conform to the minimum wedge tensile load and proof load or alternative proof load specified in Table 4. The load achieved during proof load testing shall be equal to or greater than the specified proof load.

6.2.2 When the length of the bolt makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements specified in Table 5. When bolts are tested by both full-size and machined specimen methods, the full-size test shall take precedence.

6.2.3 Sizes 1.00 in. and smaller having a length shorter than 2½ D down to 2D, inclusive, that cannot be wedge tensile tested shall be axially tension tested full size and shall conform to the minimum tensile load and proof load or alternate proof load specified in Table 4. Sizes 1.00 in. and smaller having a length shorter than 2D that cannot be axially tensile tested shall be qualified on the basis of hardness.

6.2.4 For bolts on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event of low hardness readings.

6.3 Rotational Capacity Test:

6.3.1 Definition—The rotational capacity test is intended to evaluate the presence of a lubricant, the efficiency of the lubricant, and the compatibility of assemblies as represented by the components selected for testing.

6.3.2 Requirement—Zinc-coated bolts, zinc-coated washers, and zinc-coated and lubricated nuts tested full size in an assembled joint or tension measuring device, in accordance with 10.2, shall not show signs of failure when subjected to the nut rotation in Table 6. The test shall be performed by the responsible party (see Section 14) prior to shipment after zinc coating and lubrication of nuts (see 10.2 and Note 5).

### TABLE 1 Chemical Requirements for Type 1 Bolts

<table>
<thead>
<tr>
<th>Element</th>
<th>Carbon Steel</th>
<th>Carbon Boron Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heat Analysis</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>0.30–0.52</td>
<td>0.28–0.55</td>
</tr>
<tr>
<td>Manganese, min</td>
<td>0.60</td>
<td>0.57</td>
</tr>
<tr>
<td>Phosphorus, max</td>
<td>0.040</td>
<td>0.048</td>
</tr>
<tr>
<td>Sulfur, max</td>
<td>0.050</td>
<td>0.058</td>
</tr>
<tr>
<td>Silicon</td>
<td>0.10–0.30</td>
<td>0.08–0.32</td>
</tr>
<tr>
<td>Boron</td>
<td>0.0005–0.003</td>
<td>0.0005–0.003</td>
</tr>
</tbody>
</table>

| Element            | Alloy Steel  |                  |
|--------------------|--------------|                  |
| **Heat Analysis**  |              |                  |
| Carbon             | 0.30–0.52    | 0.28–0.55        |
| Manganese, min     | 0.60         | 0.57             |
| Phosphorus, max    | 0.035        | 0.040            |
| Sulfur, max        | 0.040        | 0.045            |
| Silicon            | 0.15–0.35    | 0.13–0.37        |

| Element            | Alloys       |                  |
|--------------------|--------------|                  |
| **Heat Analysis**  |              |                  |
| Carbon             | 0.30–0.52    | 0.28–0.55        |
| Manganese, min     | 0.60         | 0.57             |
| Phosphorus, max    | 0.035        | 0.040            |
| Sulfur, max        | 0.040        | 0.045            |
| Silicon            | 0.15–0.35    | 0.13–0.37        |
| Boron              | 0.0005–0.003 | 0.0005–0.003     |

*AA Steel, as defined by the American Iron and Steel Institute, shall be considered to be alloy when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: Manganese, 1.65%; silicon, 0.60%; copper, 0.60% or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99%, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying elements added to obtain a desired alloying effect.*
6.3.3 Acceptance Criterion—The bolt and nut assembly shall be considered as non-conforming if the assembly fails to pass any one of the following specified requirements:

6.3.3.1 Inability to install the assembly to the nut rotation in Table 6.

6.3.3.2 Inability to remove the nut after installing to the rotation specified in Table 6.

6.3.3.3 Shear failure of the threads as determined by visual examination of bolt and nut threads following removal.

6.3.3.4 Torsional or torsional/tension failure of the bolt. Elongation of the bolt, in the threads between the nut and bolt head, is to be expected at the required rotation and is not to be classified as a failure.

7. Dimensions

7.1 Head and Body:

7.1.1 The bolts shall conform to the dimensions for heavy hex structural bolts specified in ANSI/ASME B18.2.6.

7.1.2 The thread length shall not be changed except as provided in Supplementary Requirement S1. Bolts with thread lengths other than those required by this specification shall be ordered under Specification A 449.

7.2 Threads:
TABLE 4 Tensile Load Requirements for Full-Size Bolts

| Bolt Size, Threads per Inch, and Series Designation | Stress Area, $A$ | Tensile Load, $B$ | Proof Load, $C$ | Alternative Proof Load, $D$ | Yield Strength, $E$
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Column 1</td>
<td>Column 2</td>
<td>Column 3</td>
<td>Column 4</td>
<td>Column 5</td>
<td></td>
</tr>
<tr>
<td>1 1/2 –8 UN</td>
<td>0.606</td>
<td>72 700</td>
<td>51 500</td>
<td>55 750</td>
<td></td>
</tr>
<tr>
<td>1 1/4 –8 UN</td>
<td>0.790</td>
<td>82 950</td>
<td>58 450</td>
<td>64 000</td>
<td></td>
</tr>
<tr>
<td>1 1/8 –8 UN</td>
<td>0.969</td>
<td>101 700</td>
<td>71 700</td>
<td>78 500</td>
<td></td>
</tr>
<tr>
<td>1 –8 UNC</td>
<td>1.000</td>
<td>105 000</td>
<td>74 000</td>
<td>81 000</td>
<td></td>
</tr>
<tr>
<td>7/8 –9 UNC</td>
<td>1.155</td>
<td>121 300</td>
<td>85 450</td>
<td>93 550</td>
<td></td>
</tr>
<tr>
<td>1/2 –10 UNC</td>
<td>1.233</td>
<td>129 500</td>
<td>91 250</td>
<td>99 870</td>
<td></td>
</tr>
<tr>
<td>1/4 –10 UNC</td>
<td>1.405</td>
<td>147 500</td>
<td>104 000</td>
<td>113 800</td>
<td></td>
</tr>
<tr>
<td>1/8 –10 UNC</td>
<td>1.492</td>
<td>156 700</td>
<td>110 400</td>
<td>120 850</td>
<td></td>
</tr>
</tbody>
</table>

$A$ The stress area is calculated as follows:

$$A = 0.7854 \times (D - (0.9743/n))^2$$

where:

$A = \text{stress area, in.}^2$

$D = \text{nominal bolt size, and}$

$n = \text{threads per inch.}$

Loads tabulated are based on the following:

<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
<th>Column 4</th>
<th>Column 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 to 1, incl</td>
<td>120 000 psi</td>
<td>85 000 psi</td>
<td>92 000 psi</td>
<td></td>
</tr>
<tr>
<td>1/4 to 1 1/2, incl</td>
<td>105 000 psi</td>
<td>74 000 psi</td>
<td>81 000 psi</td>
<td></td>
</tr>
</tbody>
</table>

7.2.3 The gaging limit for bolts shall be verified during manufacture. In case of dispute, a calibrated thread ring gage of the same size as the oversize limit in 7.2.2 (Class X tolerance, gage tolerance plus) shall be used to verify compliance. The gage shall assemble with hand effort following application of light machine oil to prevent galling and damage to the gage. These inspections, when performed to resolve controversy, shall be conducted at the frequency specified in the quality assurance provisions of ASME B18.2.6.

8. Workmanship

8.1 The allowable limits, inspection, and evaluation of the surface discontinuities, quench cracks, forging cracks, head bursts, shear bursts, seams, folds, thread laps, voids, tool marks, nicks, and gouges shall be in accordance with Specification F 788/F 788M (See Note 4).

NOTE 4—Specification F 788/F 788M nor F 1470 guarantee 100% freedom from head bursts. Sampling is designed to provide a 95% confidence level of freedom from head bursts in any test lot. Head bursts, within the limits in Specification F 788/F 788M, are unsightly but do not affect mechanical properties or functional requirements of the bolt.

9. Number of Tests and Retests

9.1 Testing Responsibility:

9.1.1 Each lot shall be tested by the manufacturer prior to shipment in accordance with the lot identification control quality assurance plan in 9.2 through 9.5.

9.1.2 When bolts are furnished by a source other than the manufacturer, the Responsible Party as defined in 14 shall be responsible for assuring all tests have been performed and the bolts comply with the requirements of this specification (see 4.5).

9.2 Purpose of Lot Inspection—The purpose of a lot inspection program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective it is essential that secondary processors, distributors, and purchasers maintain the identification and integrity of each lot until the product is installed.

9.3 Lot Method—All bolts shall be processed in accordance with a lot identification-control quality assurance plan. The manufacturer, secondary processors, and distributors shall identify and maintain the integrity of each production lot of bolts from raw-material selection through all processing operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

9.4 Lot Definition—A lot shall be a quantity of uniquely identified heavy hex structural bolts of the same nominal size and length produced consecutively at the initial operation from a single mill heat of material and processed at one time, by the same process, in the same manner so that statistical sampling is valid. The identity of the lot and lot integrity shall be maintained throughout all subsequent operations and packaging.
9.5 Number of Tests—The minimum number of tests from each lot for the tests specified below shall be as follows:

<table>
<thead>
<tr>
<th>Tests</th>
<th>Number of Tests in Accordance With</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness, tensile strength, proof load, and rotational capacity</td>
<td>Guide F 1470</td>
</tr>
<tr>
<td>Coating weight/thickness</td>
<td>The referenced coating specification*</td>
</tr>
<tr>
<td>Surface discontinuities</td>
<td>Specification F 788/ F 788M</td>
</tr>
<tr>
<td>Dimensions and thread fit</td>
<td>ASME B18.2.6</td>
</tr>
</tbody>
</table>

*Guide F 1470 applies if the coating specification does not specify a testing frequency.

10. Test Methods

10.1 Tensile, Proof Load, and Hardness:

10.1.1 Tensile, proof load, and hardness tests shall be conducted in accordance with Test Methods F 606.

10.1.2 Tensile strength shall be determined using the Wedge or Axial Tension Testing Method of Full Size Product Method or the Machined Test Specimens Method depending on size and length as specified in 6.2.1-6.2.4. Fracture on full-size tests shall be in the body or threads of the bolt without a fracture at the junction of the head and body.

10.1.3 Proof load shall be determined using Method 1, Length Measurement, or Method 2, Yield Strength, at the option of the manufacturer.

10.2 Rotational Capacity—The zinc-coated bolt shall be placed in a steel joint or tension measuring device and assembled with a zinc-coated washer and a zinc-coated and lubricated nut with which the bolt is intended to be used (see Note 5). The nut shall have been provided with the lubricant described in the last paragraph of the Manufacturing Processes section of Specification A 563. The joint shall be one or more flat structural steel plates or fixture stack up with a total thickness, including the washer, such that 3 to 5 full threads of the bolt are located between the bearing surfaces of the bolt head and nut. The hole in the joint shall have the same nominal diameter as the hole in the washer. The initial tightening of the nut shall produce a load in the bolt not less than 10 % of the specified proof load. After initial tightening, the nut position shall be marked relative to the bolt, and the rotation shown in Table 6 shall be applied. During rotation, the bolt head shall be restrained from turning.

NOTE 5—Rotational capacity tests shall apply only to matched assembly lots that contain on A 325 bolt, one A 563 lubricated nut, and one F 436 washer that have been zinc coated in accordance with either Specifications A 153 or B 695. Both the bolt and nut components of the matched assembly shall be zinc coated using the same process.

11. Inspection

11.1 If the inspection described in 11.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

11.2 The purchaser’s representative shall have free entry to all parts of the manufacturer’s works, or supplier’s place of business, that concern the manufacture or supply of the material ordered. The manufacturer or supplier shall afford the purchaser’s representative all reasonable facilities to satisfy himself that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser’s representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the manufacturer’s works or supplier’s place of business.

12. Rejection and Rehearing

12.1 Disposition of nonconforming bolts shall be in accordance with the Guide F 1470 section titled “Disposition of Nonconforming Lots.”

13. Certification

13.1 When specified on the purchase order, the manufacturer or supplier, whichever is the responsible party as defined in Section 14, shall furnish the purchaser a test reports that includes the following:

13.1.1 Heat analysis, heat number, and a statement certifying that heats having the elements listed in 5.4 intentionally added were not used to produce the bolts,

13.1.2 Results of hardness, tensile, and proof load tests,

13.1.3 Results of rotational capacity tests. This shall include the test method used (solid plate or tension measuring device); and the statement “Nuts lubricated” for zinc-coated nuts when shipped with zinc-coated bolts,

13.1.4 Zinc coating measured coating weight/thickness for coated bolts,

13.1.5 Statement of compliance of visual inspection for surface discontinuities (Section 8),

13.1.6 Statement of compliance with dimensional and thread fit requirements,

13.1.7 Lot number and purchase order number,

13.1.8 Complete mailing address of responsible party, and
13.1.9 Title and signature of the individual assigned certification responsibility by the company officers.
13.2 Failure to include all the required information on the test report shall be cause for rejection.

14. Responsibility

14.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

15. Product Marking

15.1 Manufacturer’s Identification— All Type 1 and 3 bolts shall be marked by the manufacturer with a unique identifier to identify the manufacturer or private label distributor, as appropriate.

15.2 Grade Identification:
15.2.1 Type 1 bolts shall be marked “A 325.”
15.2.2 Type 3 bolts shall be marked “A 325” with the “A 325” underlined. The use of additional distinguishing marks to indicate that the bolts are weathering steel shall be at the manufacturer’s option.

15.3 Marking Location and Methods—All marking shall be located on the top of the bolt head and shall be either raised or depressed at the manufacturer’s option.

15.4 Acceptance Criteria—Bolts which are not marked in accordance with these provisions shall be considered nonconforming and subject to rejection.

15.5 Type and manufacturer’s or private label distributor’s identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

16. Packaging and Package Marking

16.1 Packaging:
16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.
16.1.2 When zinc coated nuts are included on the same order as zinc coated bolts, the bolts and nuts shall be shipped in the same container.
16.1.3 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

16.2 Package Marking:
16.2.1 Each shipping unit shall include or be plainly marked with the following information:
16.2.1.1 ASTM designation and type,
16.2.1.2 Size,
16.2.1.3 Name and brand or trademark of the manufacturer,
16.2.1.4 Number of pieces,
16.2.1.5 Lot number; when nuts, washers or direct tension indicators, or combination thereof, are ordered with A 325 heavy hex structural bolts, the shipping unit shall be marked with the lot number in addition to the marking required by the applicable product specification,
16.2.1.6 Purchase order number, and
16.2.1.7 Country of origin.

17. Keywords
17.1 bolts; carbon steel; steel; structural; weathering steel

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order. Details of these supplementary requirements shall be agreed upon in writing between the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Bolts Threaded Full Length

S1.1 Bolts with nominal lengths equal to or shorter than four times the nominal bolt diameter shall be threaded full length. Bolts need not have a shoulder, and the distance from the underhead bearing surface to the first complete (full form) thread, as measured with a GO thread ring gage, assembled by hand as far as the thread will permit, shall not exceed the length of 2½ threads for bolt sizes 1 in. and smaller, and 3½ threads for bolt sizes larger than 1 in.

S1.2 Bolts shall be marked in accordance with Section 15, except that the symbol shall be “A 325 T” instead of “A 325.”
SUMMARY OF CHANGES

Committee F16 has identified the location of selected changes to this standard since the last issue, A 325–02, that may impact the use of this standard. (Approved Jan. 1, 2004.)

(1) Revised Certification Section 13.1.5 to require statement of compliance of visual inspection for all surface discontinuities.

Committee F16 has identified the location of selected changes to this standard since the last issue, A 325–01, that may impact the use of this standard. (Approved Jan. 10, 2002.)

(1) In 1.4 limited specification to heavy hex structural bolts only.
(2) In 4.1 revised to require that Type 3 bolts be quenched in oil.
(3) In 4.5.1 revised to require retesting only for properties affected by the secondary processing.
(4) In 4.5.2 rephrased to preclude the implication that black bolts require rotational capacity testing.
(5) In Table 2, reduced the phosphorus limits for compositions A, D, E, and F and the sulfur limits for compositions A, B, and D.
(6) In 6.2.1 revised the minimum length for full-size wedge testing.
(7) In 6.2.3 provided for full-size axially tension testing bolts shorter than 2 1/8 D down to 2D. Also added requirements for qualifying short bolts on the basis of hardness.
(8) In Table 3, Hardness, changed 3D to 2D for sizes 1.00 in. and smaller
(9) Added Table 5 specifying tensile, elongation, and reduction in area requirements for machined specimens.
(10) In 7.1.1 deleted all wording that permitted the purchaser to specify dimensions other than “heavy hex structural.”
(11) In 7.1.1 changed the dimensional reference from B18.2.1 to B18.2.6.
(12) 7.2.2 revised to specify maximum pitch and major diameter limits for mechanically coated bolts.
(13) Deleted Table 7 (formerly Table 6), “Sample Size for Inspection of Hot-Dip or Mechanically Deposited Zinc-Coated Threads” and referenced ASME B18.2.6, which includes references for testing frequency.
(14) Deleted former section 9, “Head Bursts,” and included the requirements by reference to Specification F 788/F 788M in 8.1.
(15) In 9.3 and 9.4 changed “Production Lot” to “Lot” and redefined “Lot.”
(16) 9.5, “Number of Tests,” revised to invoke Specification F 1470 for hardness, tensile, proof load, and rotational capacity tests. Coating weight/thickness and surface discontinuities sampling referenced to the applicable spec. Dimensional and thread compliance sampling referenced to ASME B18.2.6.
(17) Section 12, “Rejection and Rehearing,” revised to invoke F 1470.
(18) In 15.2.1 deleted option permitting marking with three radial lines 120° apart.
Designation: A 325M – 04

METRIC

Standard Specification for
Structural Bolts, Steel, Heat Treated 830 MPa Minimum
Tensile Strength [Metric]¹

This standard is issued under the fixed designation A 325M; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers two types of quenched and tempered, steel, metric heavy hex structural bolts having a
minimum tensile strength of 830 MPa (Note 1).

1.2 The bolts are intended for use in structural connections. These connections are comparable to those covered under the
requirements of the Specification for Structural Joints using ASTM A 325 or A 490 bolts, approved by the Research
Council on Structural Connections; endorsed by the American Institute of Steel Construction and by the Industrial Fastener
Institute.³

1.3 The bolts are furnished in sizes M12 to M136 inclusive. They are designated by type denoting chemical composition as
follows:

1.3.1 Type 1—Medium-carbon, carbon boron, medium carbon alloy, or alloy boron steel.

1.3.2 Type 2—Withdrawn in 2003.

1.3.3 Type 3—Weathering Steel.

1.4 This specification is applicable to metric heavy hex, structural bolts only.

1.5 Terms used in this specification are defined in Specification F 1789.

1.6 The following safety hazards caveat pertains only to the
test methods portion, Section 10, of this specification. This
standard does not purport to address all of the safety concerns,
if any, associated with its use. It is the responsibility of the user
of this standard to establish appropriate safety and health
practices and determine the applicability of regulatory require-
ments prior to use.

Note 1—This specification is the metric companion to the inch pound
Specification A 325.

2. Referenced Documents

2.1 ASTM Standards: ⁴

A 153 Specification for Zinc Coating (Hot Dip) on Iron and
Steel Hardware

A 490M Specification for High-Strength Steel Bolts,
Classes 10.9 and 10.9.3, for Structural Steel Joints [Metric]

A 563M Specification for Carbon and Alloy Steel Nuts
[Metric]

A 751 Test Methods, Practices, and Terminology for
Chemical Analysis of Steel Products

B 695 Specification of Coatings of Zinc Mechanically De-
posited on Iron and Steel

D 3951 Practice for Commercial Packaging

F 436M Specification for Hardened Steel Washers [Metric]

F 606M Test Methods for Determining the Mechanical
Properties of Externally and Internally Threaded Fasteners,
Washers, and Rivets [Metric]

F 788/F 788M Specification for Surface Discontinuities of
Bolts, Screws, and Studs, Inch and Metric Series

F 959M Specification for Compressible Washer-Type Di-
rect Tension Indicators for Use with Structural Fasteners
[Metric]

F 1470 Guide for Fastener Sampling for Specified Mechani-
cal Properties and Performance Inspection

F 1789 Terminology for F16 Mechanical Fasteners

G 101 Guide for Estimating the Atmospheric Corrosion
Resistance of Low-Alloy Steels

2.2 ASME Standards:

B 1.13M Metric Screw Threads⁵

¹This specification is under the jurisdiction of ASTM Committee F16 on
Fasteners and is the direct responsibility of Subcommittee F16.02 on Steel Bolts,
Nuts, Rivets, and Washers.


²For ASME Boiler and Pressure Vessel Code applications, see related Specifi-
cation SA-325M in Section II of that Code.

³Available from American Institute of Steel Construction (AISC), One E.

⁴For referenced ASTM standards, visit the ASTM website, www.astm.org, or
contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM
Standards volume information, refer to the standard’s Document Summary page on
the ASTM website.

⁵Available from American Society of Mechanical Engineers (ASME), ASME
International Headquarters, Three Park Ave., New York, NY 10016-5990.

*A Summary of Changes section appears at the end of this standard.

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B 18.2.3.7M Metric Heavy Hex Structural Bolts
B 18.18.3M Inspection and Quality Assurance for Special Purpose Fasteners
B 18.24.1 Part Identifying Number (PIN) Code System

3. Ordering Information
3.1 Orders for heavy hex structural bolts under this specification shall include the following:
3.1.1 Quantity (number of pieces of bolts and accessories).
3.1.2 Size, including nominal bolt diameter, thread pitch and bolt length.
3.1.3 Name of product, heavy hex structural bolts.
3.1.4 When bolts threaded full length are required, Supplementary Requirement S1 shall be specified.
3.1.5 Type of bolt; Type 1 or Type 3. When the type is not specified, either Type 1 or Type 3 shall be furnished at the supplier’s option.
3.1.6 ASTM designation and year of issue.
3.1.7 Other components such as nuts, washers, and compressible washer-type direct-tension indicators, if required.
3.1.8 Zinc Coating—Specify the zinc-coating process required, for example, hot-dip, mechanically deposited, or no preference (see 4.3).
3.1.9 Other Finishes—Specify other protective finish, if required.
3.1.10 Test reports, if required (see Section 13).
3.1.11 Supplementary or special requirements, if required.
3.1.12 For establishment of a part identifying system, see ASME B18.24.1.

NOTE 2—A typical ordering description follows: 1000 pieces, 24x3 x 100, heavy hex structural bolts, Type 1 ASTM A 325M - 03, each with one hardened washer and one heavy hex nut, mechanically deposited zinc coating (see 3.1.8 for any special requirements).

3.2 Recommended Nuts:
3.2.1 Nuts conforming to the requirements of Specification A 563M are the recommended nuts for use with A 325M metric heavy hex structural bolts. The nuts shall be of the class and have a surface finish for each type of bolt as follows:

<table>
<thead>
<tr>
<th>Bolt Type and Finish</th>
<th>Nut Class and Finish Specification</th>
<th>A 563M—8 or 8S3, plain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, plain (noncoated)</td>
<td>A 563M—8 or 8S3, plain</td>
<td></td>
</tr>
<tr>
<td>1, zinc-coated</td>
<td>A 563M—10S, zinc-coated</td>
<td></td>
</tr>
<tr>
<td>3, plain</td>
<td>A 563M—8S3, plain</td>
<td></td>
</tr>
</tbody>
</table>

3.3 Recommended Washers:
3.3.1 Washers conforming to Specification F 436M are the recommended washers for use with Specification A 325M Metric heavy hex structural bolts. The washers shall have a surface finish for each type of bolt as follows:

<table>
<thead>
<tr>
<th>Bolt Type and Finish</th>
<th>Washer Finish</th>
<th>A 563M—10S, zinc-coated</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, plain (noncoated)</td>
<td>plain (noncoated)</td>
<td></td>
</tr>
<tr>
<td>1, zinc-coated</td>
<td>zinc-coated</td>
<td></td>
</tr>
<tr>
<td>3, plain</td>
<td>weathering steel, plain</td>
<td></td>
</tr>
</tbody>
</table>

3.4 Other Accessories:
3.4.1 When compressible washer type direct tension indicators are specified to be used with these bolts, they shall conform to the requirements in Specification F 959M Type 8.8.

4. Materials and Manufacture
4.1 Heat Treatment:
4.1.1 Type 1 bolts produced from medium carbon steel shall be quenched in a liquid medium from the austenitizing temperature.
4.1.2 Type 1 bolts produced from carbon steel to which chromium, nickel, molybdenum, or boron were intentionally added shall be quenched only in oil from the austenitizing temperature.
4.1.3 Type 3 bolts shall be quenched only in oil from the austenitizing temperature.
4.1.4 Type 1 bolts, regardless of the steel used, and Type 3 bolts, shall be tempered by reheating to not less than 427°C.
4.2 Threading—Threads shall be cut or rolled.
4.3 Zinc Coatings, Hot-dip and Mechanically Deposited:
4.3.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc coating process, for example, hot dip, mechanically deposited, or no preference.
4.3.2 When hot-dip is specified, the fasteners shall be zinc-coated by the hot-dip process and the coating shall conform to the coating weight/thickness and performance requirements of Class C of Specification A 153.

4.3.3 When mechanically deposited is specified, the fasteners shall be zinc-coated by the mechanical deposition process and the coating shall conform to the coating weight/thickness and performance requirements of Class 50 of Specification B 695.

4.3.4 When no preference is specified, the supplier shall furnish either a hot-dip zinc coating in accordance with Specification A 153, Class C, or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process and the supplier’s option is limited to one process per item with no mixed processes in a lot.

4.4 Lubrication—When zinc coated nuts are ordered with the bolts, the nuts shall be lubricated in accordance with Specification A 563M, Supplementary Requirement S1, to minimize galling.

4.5 Secondary Processing:

4.5.1 If any processing, which can affect the mechanical properties or performance of the bolts is performed after the initial testing, the bolts shall be retested for all specified mechanical properties and performance requirements affected by the reprocessing.

4.5.2 When the secondary process is heat treatment, the bolts shall be tested for all specified mechanical properties. Hot dip zinc coated bolts shall be tested for all specified mechanical properties and rotational capacity. If zinc coated nuts are

---

**TABLE 2 Chemical Requirements for Type 3 Heavy Hex Structural Bolts**

<table>
<thead>
<tr>
<th>Element</th>
<th>Composition, %</th>
<th>Type 3 Bolts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Carbon:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.33–0.40</td>
<td>0.38–0.48</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.31–0.42</td>
<td>0.36–0.50</td>
</tr>
<tr>
<td>Manganese:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.90–1.20</td>
<td>0.70–0.90</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.86–1.24</td>
<td>0.67–0.93</td>
</tr>
<tr>
<td>Phosphorus:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.035 max</td>
<td>0.06–0.12</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.040 max</td>
<td>0.06–0.125</td>
</tr>
<tr>
<td>Sulfur:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.040 max</td>
<td>0.040 max</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.045 max</td>
<td>0.045 max</td>
</tr>
<tr>
<td>Silicon:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.15–0.35</td>
<td>0.30–0.50</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.13–0.37</td>
<td>0.25–0.55</td>
</tr>
<tr>
<td>Copper:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.25–0.45</td>
<td>0.20–0.40</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.22–0.48</td>
<td>0.17–0.43</td>
</tr>
<tr>
<td>Nickel:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.25–0.45</td>
<td>0.50–0.80</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.22–0.48</td>
<td>0.47–0.83</td>
</tr>
<tr>
<td>Chromium:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.45–0.65</td>
<td>0.50–0.75</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.42–0.68</td>
<td>0.47–0.83</td>
</tr>
<tr>
<td>Vanadium:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>b</td>
<td>b</td>
</tr>
<tr>
<td>Product analysis</td>
<td>b</td>
<td>b</td>
</tr>
<tr>
<td>Molybdenum:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>b</td>
<td>0.06 max</td>
</tr>
<tr>
<td>Product analysis</td>
<td>b</td>
<td>0.07 max</td>
</tr>
<tr>
<td>Titanium:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>b</td>
<td>b</td>
</tr>
<tr>
<td>Product analysis</td>
<td>b</td>
<td>b</td>
</tr>
</tbody>
</table>

A, B, C, D, E, and F are classes of material used for Type 3 bolts. Selection of a class shall be at the option of the bolt manufacturer.

b These elements are not specified or required.
re lubricated after the initial rotational capacity tests, the assemblies shall be retested for rotational capacity. See 10.2, Note 4.

5. Chemical Composition

5.1 Type 1 bolts shall be plain carbon steel, carbon boron steel, alloy steel, or alloy boron steel at the manufacturer's option, conforming to the chemical composition specified in Table 1.

5.2 Type 3 bolts shall be weathering steel and shall conform to one of the chemical compositions specified in Table 2. The selection of the chemical composition, A, B, C, D, E, or F, shall be at the option of the bolt manufacturer. See Guide G 101 for methods of estimating the atmospheric corrosion resistance of low alloy steels.

5.3 Product analyses made on finished bolts representing each lot shall conform to the product analysis requirements specified in Table 1 or Table 2, as applicable.

5.4 Heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for bolts.

5.5 Compliance with 5.4 shall be based on certification that heats of steel having any of the listed elements intentionally added were not used to produce the bolts.

5.6 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 Hardness—The bolts shall conform to the hardness specified in Table 3.

6.2 Tensile Properties:

6.2.1 Except as permitted in 6.2.2 for long bolts, and 6.2.3 for short bolts, sizes M24 and smaller having a length of 2-1/4 D and longer; and sizes larger than M24 having a length of 3D and longer; shall be wedge tested full size and shall conform to the minimum wedge tensile load, and proof load or alternative proof load specified in Table 4. The load achieved during proof load testing shall be equal to or greater than the specified proof load.

6.2.2 When the length of the bolt makes full size testing impractical, machined specimens shall be tested and shall conform to the requirements specified in Table 5. When bolts are tested by both full size and machined specimen methods, the full size test shall take precedence.

### TABLE 3 Hardness Requirements for Bolts

<table>
<thead>
<tr>
<th>Bolt Size, mm</th>
<th>Bolt Length, mm</th>
<th>Brinell Min</th>
<th>Brinell Max</th>
<th>Rockwell C Min</th>
<th>Rockwell C Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>M12 to M24, incl</td>
<td>Less than 2D</td>
<td>253</td>
<td>319</td>
<td>25</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>2D and over</td>
<td>...</td>
<td>319</td>
<td>...</td>
<td>34</td>
</tr>
<tr>
<td>M25 to M36, incl</td>
<td>Less than 3D</td>
<td>223</td>
<td>286</td>
<td>19</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>3D and over</td>
<td>...</td>
<td>286</td>
<td>...</td>
<td>30</td>
</tr>
</tbody>
</table>

A Sizes M24 and smaller having a length shorter than 2D and sizes larger than M24 having a length shorter than 3D are subject only to minimum and maximum hardness. $D =$ Nominal diameter or thread size.

### TABLE 4 Tensile Load and Proof Load Requirements for Full-Size Bolts

<table>
<thead>
<tr>
<th>Nominal Diameter and Thread Pitch</th>
<th>Stress Area, $A^A$ mm²</th>
<th>Tensile Load, $T_{	ext{min}}$, min.</th>
<th>Proof Load, $P_{	ext{min}}$, Method</th>
<th>Alternative Proof Load, $P_{	ext{min}}$, Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column 1</td>
<td>Column 2</td>
<td>Column 3</td>
<td>Column 4</td>
<td>Column 5</td>
</tr>
<tr>
<td>M12 × 1.75</td>
<td>84.3</td>
<td>70</td>
<td>50.6</td>
<td>55.6</td>
</tr>
<tr>
<td>M16 × 2</td>
<td>157</td>
<td>130</td>
<td>94.2</td>
<td>104</td>
</tr>
<tr>
<td>M20 × 2.5</td>
<td>245</td>
<td>203</td>
<td>147</td>
<td>162</td>
</tr>
<tr>
<td>M22 × 2.5</td>
<td>303</td>
<td>251</td>
<td>182</td>
<td>200</td>
</tr>
<tr>
<td>M24 × 3</td>
<td>353</td>
<td>293</td>
<td>212</td>
<td>233</td>
</tr>
<tr>
<td>M27 × 3</td>
<td>459</td>
<td>381</td>
<td>275</td>
<td>303</td>
</tr>
<tr>
<td>M30 × 3.5</td>
<td>561</td>
<td>466</td>
<td>337</td>
<td>370</td>
</tr>
<tr>
<td>M36 × 4</td>
<td>817</td>
<td>678</td>
<td>490</td>
<td>539</td>
</tr>
</tbody>
</table>

$^A$ Stress Area, $A = 0.7854(D - 0.9382P)^2$

Where:

$D =$ nominal bolt diameter, mm, and $P =$ thread pitch, mm.

### TABLE 5 Tensile Strength Requirements for Specimens Machined from Bolts

<table>
<thead>
<tr>
<th>Nominal Diameter, mm</th>
<th>Tensile Strength, min, MPa</th>
<th>Yield Strength, min, MPa</th>
<th>Elongation in 4D, min, %</th>
<th>Reduction of Area, min, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>M12 to M36 incl</td>
<td>830</td>
<td>660</td>
<td>14</td>
<td>35</td>
</tr>
</tbody>
</table>

6.2.3 Sizes M24 and smaller having a length shorter than 2-1/4 D down to 2D inclusive, which cannot be wedge tensile tested shall be axially tension tested full size and shall conform to the minimum tensile load and proof load, or alternate proof load specified in Table 4. Sizes M24 and smaller having a length shorter than 2D, which cannot be axially tensile tested shall be qualified on the basis of hardness.

6.2.4 For bolts on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event of low hardness readings.

6.3 Rotational Capacity Test:

6.3.1 Definition—The rotational capacity test is intended to evaluate the presence of a lubricant, the efficiency of the lubricant, and the compatibility of assemblies as represented by the components selected for testing.

6.3.2 Requirement—Zinc-coated bolts, zinc-coated washers and zinc-coated and lubricated nuts tested full size in an assembled joint or tension measuring device, in accordance with 10.2, shall not show signs of failure when subjected to the nut rotation in Table 6. The test shall be performed by the responsible party (see Section 14) prior to shipment after zinc coating and lubrication of nuts. See 10.2, Note 4.

### TABLE 6 Rotational Capacity Test for Zinc-Coated Bolts

<table>
<thead>
<tr>
<th>Nominal Bolt Length, mm</th>
<th>Nut Rotation, degrees (turn), min</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D and shorter</td>
<td>180 (½)</td>
</tr>
<tr>
<td>Over 2D to 3D incl</td>
<td>240 (½)</td>
</tr>
<tr>
<td>Over 3D to 4D incl</td>
<td>300 (½)</td>
</tr>
<tr>
<td>Over 4D to 8D incl</td>
<td>360 (1)</td>
</tr>
<tr>
<td>Over 8D</td>
<td>420 (1-1/4)</td>
</tr>
</tbody>
</table>
6.3.3 Acceptance Criterion—The bolt and nut assembly shall be considered as non-conforming if the assembly fails to pass any one of the following specified requirements:

6.3.3.1 Inability to install the assembly to the nut rotation in Table 6.

6.3.3.2 Inability to remove the nut after installing to the rotation specified in Table 6.

6.3.3.3 Shear failure of the threads as determined by visual examination of bolt and nut threads following removal.

6.3.3.4 Torsional or torsional/tension failure of the bolt. Elongation of the bolt, in the threads between the nut and bolt head, is to be expected at the required rotation and is not to be classified as a failure.

7. Dimensions

7.1 Head and Body:

7.1.1 The bolts shall conform to the dimensions for metric heavy hex structural bolts specified in ASME B18.2.3.7M.

7.1.2 The thread length shall not be changed except as provided in Supplementary Requirement S1. Bolts with thread lengths other than those required by this specification shall be ordered under Specification F 568M.

7.2 Threads:

7.2.1 Uncoated—Threads shall be Metric Coarse Thread Series as specified in ASME B1.13M and shall have Grade 6g tolerances.

7.2.2 Coated:

7.2.2.1 Unless otherwise specified, zinc-coated bolts, to be used with zinc-coated nuts or tapped holes, which are tapped oversize in accordance with Specification A 563, shall have 6g threads before hot-dip or mechanically deposited zinc coating. After zinc coating, the pitch diameter and major diameter shall not exceed the Class 6g limits by more than the following amounts:

<table>
<thead>
<tr>
<th>Nominal Bolt Diameter</th>
<th>Oversize Limit, mm&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Hot Dip Zinc</th>
<th>Mechanical Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>M12</td>
<td>0.36</td>
<td>0.24</td>
<td></td>
</tr>
<tr>
<td>M16</td>
<td>0.42</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>M20</td>
<td>0.53</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>M24</td>
<td>0.64</td>
<td>0.43</td>
<td></td>
</tr>
<tr>
<td>M27</td>
<td>0.64</td>
<td>0.43</td>
<td></td>
</tr>
<tr>
<td>M30</td>
<td>0.75</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>M36</td>
<td>0.86</td>
<td>0.58</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Hot-dip zinc nuts are tapped oversize after coating and mechanical zinc-coated nuts are tapped oversize before coating.

7.2.3 The gaging limit for bolts shall be verified during manufacture. In case of dispute, a calibrated thread ring gage of the same size as the oversize limit in 7.2.2 (Class X tolerance, gage tolerance plus) shall be used to verify compliance. The gage shall assemble with hand effort following application of light machine oil to prevent galling and damage to the gage. These inspections, when performed to resolve controversy, shall be conducted at the frequency specified in the quality assurance provisions of ASME B18.2.6.

8. Workmanship

8.1 The allowable limits, inspection and evaluation of the surface discontinuities quench cracks, forging cracks, head bursts, shear bursts, seams, folds, thread laps, voids, tool marks, nicks and gouges shall be in accordance with Specification F 788/F 788M. (Note 3)

9. Number of Tests and Retests

9.1 Testing Responsibility:

9.1.1 Each lot shall be tested by the manufacturer prior to shipment in accordance with the lot identification control quality assurance plan in 9.2-9.5.

9.1.2 When bolts are furnished by a source other than the manufacturer, the Responsible Party as defined in 14.1 shall be responsible for assuring all tests have been performed and the bolts comply with the requirements of this specification (see 4.5).

9.2 Purpose of Lot Inspection—The purpose of a lot inspection program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective it is essential that secondary processors, distributors, and purchasers maintain the identification and integrity of each lot until the product is installed.

9.3 Lot Method—All bolts shall be processed in accordance with a lot identification-control quality assurance plan. The manufacturer, secondary processors, and distributors shall identify and maintain the integrity of each production lot of bolts from raw-material selection through all processing operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

9.4 Lot Definition—A lot shall be a quantity of uniquely identified heavy hex structural bolts of the same nominal size and length produced consecutively at the initial operation from a single mill heat of material and processed at one time, by the same processor in the same manner so that statistical sampling is valid. The identity of the lot and lot integrity shall be maintained throughout all subsequent operations and packaging.

9.5 Number of Tests—The minimum number of tests from each lot for the tests specified below shall be as follows:

<table>
<thead>
<tr>
<th>Tests</th>
<th>Number of Tests in Accordance with</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness, Tensile Strength, Proof Load and Rotational Capacity</td>
<td>Guide F 1470</td>
</tr>
<tr>
<td>Coating Weight / Thickness</td>
<td>The referenced coating specification&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Surface Discontinuities Dimensions and Thread Fit</td>
<td>Specification F 788/F 788M</td>
</tr>
<tr>
<td>Dimensions and Thread Fit</td>
<td>ASME B18.2.6</td>
</tr>
</tbody>
</table>

<sup>a</sup> Guide F 1470 if the coating specification does not specify a testing frequency.

10. Test Methods

10.1 Tensile, Proof Load, and Hardness:

10.1.1 Tensile, proof load and hardness tests shall be conducted in accordance with Test Methods F 606M.

10.1.2 Tensile strength shall be determined using the Wedge or Axial Tension Testing Method of Full Size Product Method or the Machined Test Specimens Method depending on size and length as specified in 6.2.1-6.2.3. Fracture on full size tests
shall be in the body or threads of the bolt without a fracture at the junction of the head and body.

10.1.3 Proof load shall be determined using Method 1, Length measurement; or Method 2, Yield Strength; at the option of the manufacturer.

10.2 Rotational Capacity (Note 4)—The zinc-coated bolt shall be placed in a steel joint or tension measuring device and assembled with a zinc-coated washer and a zinc-coated and lubricated nut with which the bolt is intended to be used. The nut shall have been provided with the lubricant described in the last paragraph of the Manufacturing Processes section of Specification A 563M. The joint shall be one or more flat structural steel plates or fixture stack up with a total thickness, including the washer, such that 3 to 5 full threads of the bolt are located between the bearing surfaces of the bolt head and nut. The hole in the joint shall have the same nominal diameter as the hole in the washer. The initial tightening of the nut shall produce a load in the bolt not less than 10 % of the specified proof load. After initial tightening, the nut position shall be marked relative to the bolt, and the rotation shown in Table 6 shall be applied. During rotation, the bolt head shall be restrained from turning.

Note 4—Rotational capacity tests shall apply only to matched assembly lots that contain one A 325M bolt, one A 563M lubricated nut, and one F 436M washer which have been zinc-coated in accordance with the requirements in 4.3. Both the bolt and nut components of the matched assembly shall be zinc-coated using the same process.

11. Inspection

11.1 If the inspection described in 11.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

11.2 The purchaser’s representative shall have free entry to all parts of the manufacturer’s works, or supplier’s place of business, that concern the manufacture or supply of the material ordered. The manufacturer or supplier shall afford the purchaser’s representative all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser’s representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the manufacturer’s works or supplier’s place of business.

12. Rejection and Rehearing

12.1 Disposition of nonconforming bolts shall be in accordance with Guide F 1470 section titled “Disposition of Nonconforming Lots.”

13. Certification

13.1 When specified on the purchase order, the manufacturer or supplier, whichever is the responsible party as defined in Section 14, shall furnish the purchaser test reports which includes the following:

13.1.1 Heat analysis, heat number, and a statement certifying that heats having the elements listed in 5.4 and intentionally added were not used to produce the bolts,

13.1.2 Results of hardness, tensile, and proof load tests,

13.1.3 Results of rotational capacity tests. This shall include the test method used (solid plate or tension measuring device); and the statement “Nuts Lubricated” for zinc-coated nuts when shipped with zinc-coated bolts,

13.1.4 Zinc coating measured coating weight/thickness for coated bolts,

13.1.5 Statement of compliance of visual inspection for surface discontinuities (Section 8),

13.1.6 Statement of compliance with dimensional and thread fit requirements,

13.1.7 Lot number and purchase order number,

13.1.8 Complete mailing address of responsible party, and

13.1.9 Title and signature of the individual assigned certification responsibility by the company officers.

13.2 Failure to include all the required information on the test report shall be cause for rejection.

14. Responsibility

14.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

15. Product Marking

15.1 Manufacturer’s Identification—All Type 1 and 3 bolts shall be marked by the manufacturer with a unique identifier to identify the manufacturer or private label distributor, as appropriate.

15.2 Grade Identification:

15.2.1 Type 1 bolts shall be marked “A 325M” and “8S.” In addition, bolts marked “8.8S” shall be an acceptable marking provided they also meet the requirements of ISO 7412.

15.2.2 Type 3 bolts shall be marked “A 325M” (with the A 325M underlined) and “8S3.” In addition, bolts marked “8.8S3” shall be an acceptable marking provided they also meet requirements of ISO 7412. The use of additional distinguishing marks to indicate the bolts are weathering steel shall be at the manufacturer’s discretion.

15.3 Marking Location and Methods—All marking shall be located on the top of the bolt head and shall be either raised or depressed at the manufacturer’s option. The base of the metric property class numerals 8S and 8S3 shall be positioned towards the closest periphery of the head.

15.4 Acceptance Criteria—Bolts which are not marked in accordance with these provisions shall be considered nonconforming and subject to rejection.

15.5 Type (property class) and manufacturer’s or private label distributor’s identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

16. Packaging and Package Marking

16.1 Packaging:

16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.
16.1.2 When zinc-coated nuts are included on the same order as zinc-coated bolts, the bolts and nuts shall be shipped in the same container.

16.1.3 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

16.2 Package Marking:

16.2.1 Each shipping unit shall include or be plainly marked with the following information:

16.2.1.1 ASTM designation and type,

16.2.1.2 Size,

16.2.1.3 Name and brand or trademark of the manufacturer,

16.2.1.4 Number of pieces,

16.2.1.5 Lot number,

16.2.1.6 Purchase order number, and

16.2.1.7 Country of origin.

17. Keywords

17.1 alloy steel; bolts; carbon steel; metric; steel; structural; weathering steel

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order. Details of these supplementary requirements shall be agreed upon in writing between the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Bolts Threaded Full Length

S1.1 Bolts with nominal lengths equal to or shorter than four times the nominal bolt diameter shall be threaded full length. Bolts need not have a shoulder, and the distance from the underhead bearing surface to the first complete (full form) thread, as measured with a GO thread ring gage, assembled by hand as far as the thread will permit, shall not exceed the length of 2½ threads for bolt sizes M24 and smaller, and 3½ threads for bolt sizes larger than M24.

S1.2 Bolts shall be marked in accordance with Section 15 except that the symbol shall be “A 325MT” instead of “A 325M”.

SUMMARY OF CHANGES

Committee F16 has identified the location of selected changes to this standard since the last issue, A 325M–03, that may impact the use of this standard. (Approved Jan. 1, 2004.)

(1) Revised Certification Section 13.1.5 to require statement of compliance of visual inspection for all surface discontinuities.

(2) General revision to update specification, remove dependence on F 568, and align with A 325 format and requirements. Changes include but are not limited to the following.

(3) Section 1.3—Deleted Type 2 low carbon martensite steel.

(4) Table 1—Expanded chemical composition to include alloy steel and alloy boron steel.

(5) Section 6.3—Added a Rotational Capacity test.

(6) Section 10—Deleted the shipping lot method of inspection.

(7) Section 10—Expanded number of tests to include Dimension and Thread Fit.

(8) Section 15—Provided for both “A 325M” and metric property class marking.

(9) Table 4—Expanded spec to add the M12 × 1.75 size.

(10) Added Supplementary Requirement S1 to cover bolts threaded full length.
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Designation: A 354 – 03a

Standard Specification for
Quenched and Tempered Alloy Steel Bolts, Studs, and Other
Externally Threaded Fasteners

This standard is issued under the fixed designation A 354; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

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1 This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.02 on Steel Bolts, Nuts, Rivets, and Washers.

1. Scope

1.1 This specification covers the chemical and mechanical requirements of quenched and tempered alloy steel bolts, studs, and other externally threaded fasteners in diameter for application at normal atmospheric temperatures, where high strength is required and for limited application at elevated temperature (Note 1). Any alloy steel capable of meeting the minimum mechanical and chemical properties set forth in this specification may be used.

NOTE 1—For bolts, studs, or other externally threaded fasteners, to be used at elevated temperatures, refer to Specification A 193/A 193M.

1.2 Two levels of bolting strength are covered, designated Grades BC and BD. Selection will depend upon design and the stresses and service for which the product is to be used.

NOTE 2—Quenched and tempered alloy steel bolts for structural steel joints up through 1 1/2 in. in diameter are covered in Specification A 490. Alloy steel bolts, studs, and other externally threaded fasteners (that is, heavy hex-structural bolts over 1 1/2 in., hex bolts, anchor bolts, and countersunk bolts) exhibiting similar mechanical properties to bolts conforming to Specification A 490 shall be covered by Grade BD of this specification.

When bolts of Grade BD of this specification are considered for pretensioned applications in excess of 50% of the bolt tensile strength, the additional requirements of head size, maximum tensile strength, nut size and strength, washer hardness, tests, and inspections contained in Specification A 490 should be carefully considered.

1.3 Nuts are covered in Specification A 563. Unless otherwise specified, the grade and style of nut for each grade of fastener shall be as follows:

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2 For ASME Boiler and Pressure Vessel Code applications see related Specification SA-354 in Section II of that Code.
Grade of Fastener and Surface Finish

<table>
<thead>
<tr>
<th>Nut Grade and Style</th>
<th>BC, plain (or with a coating of insufficient thickness to require over-tapped nuts)</th>
<th>C, heavy hex</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BC, zinc-coated (or with a coating thickness requiring over-tapped nuts)</td>
<td>DH, heavy hex</td>
</tr>
<tr>
<td></td>
<td>BD, all finishes</td>
<td>DH, heavy hex</td>
</tr>
</tbody>
</table>

* Nuts of other grades and styles having specified proof load stresses (Specification A 563, Table 3) greater than the specified grade and style of nut are suitable.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 Terms used in this specification are defined in Terminology F 1789 unless otherwise defined herein.

2. Referenced Documents

2.1 ASTM Standards:
- A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
- A 193/A 193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
- A 490 Specification for Structural Bolts, Alloy-Steel, Heat-Treated, 150 ksi Minimum Tensile Strength
- A 563 Specification for Carbon and Alloy Steel Nuts
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
- D 3951 Practice for Commercial Packaging
- F 436 Specification for Hardened Steel Washers
- F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
- F 788/F 788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series
- F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
- F 1789 Standard Terminology for F16 Mechanical Fasteners

2.2 ASME Standards:
- B1.1 Unified Screw Threads
- B18.2.1 Square and Hex Bolts and Screws, Inch Series
- B18.24.1 Part Identifying Number (PIN) Code System

3. Ordering Information

3.1 Orders for bolts and studs (including nuts and accessories) under this specification shall include the following:

3.1.1 ASTM designation and year of issue,
3.1.2 Name of product (that is, bolt or stud),
3.1.3 Grade (that is, BC or BD),
3.1.4 Quantities (number of pieces by size, including nuts),
3.1.5 Size and length,
3.1.6 Washers—Specify quantity and size (separate from bolts) (4.3),
3.1.7 Zinc Coating—When zinc-coated Grade BC fasteners are required, specify the zinc-coating process required, for example hot-dip, mechanically deposited, or no preference (see 4.4).
3.1.8 Other Finishes—Specify other protective finish, if required.
3.1.9 Specify if inspection at point of manufacture is required,
3.1.10 Specify if Certification (Section 14) is required, and
3.1.11 Specify additional testing (Section 9) or special requirements.
3.1.12 For establishment of a part identifying system, see ASME B18.24.1.

4. Materials and Manufacture

4.1 The steel shall be made by the open-hearth, electric-furnace, or basic-oxygen process.
4.2 All fasteners shall be heat-treated. At the option of the manufacturer, heat treatment may be performed on the raw material, during the manufacturing operations, or after final machining. Heat treatment shall consist of quenching in a liquid medium (except Grade BD sizes 1 1/2 in. and smaller shall be quenched in oil) from above the transformation temperature and then tempering by reheating to a temperature of not less than 800°F (427°C) for Grade BC and for Grade BD.

4.3 When used, suitable hardened washers shall be quenched and tempered (non-carburized) in accordance with Specification F 436.

4.4 **Zinc Coatings, Hot-Dip and Mechanically Deposited:**

4.4.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc coating process, for example, hot-dip, mechanically deposited, or no preference.

4.4.2 When “hot-dip” is specified, the fasteners shall be zinc coated by the hot-dip process in accordance with the requirements of Class C of Specification A 153/A 153M.

4.4.3 When mechanically deposited is specified, the fasteners shall be zinc-coated by the mechanical-deposition process in accordance with the requirements of Class 50 of Specification B 695.

4.4.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification A 153/A 153M, Class C or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process and the supplier’s option is limited to one process per item with no mixed processes in a lot.

**Note 3**—When the intended application requires that assembled tension exceeds 50 % of minimum bolt proof load, an anti-galling lubricant may be needed. Application of such lubricant to nuts and a test of the lubricant efficiency are provided in Supplementary Requirement S1 of Specification A 563 and should be specified when required.

4.5 Zinc-coated bolts and nuts shall be shipped in the same container unless specifically requested otherwise by the purchaser.

**Note 4**—Research conducted on bolts of similar material and manufacture indicates that hydrogen-stress cracking or stress cracking corrosion may occur on hot-dip galvanized Grade BD bolts.

5. **Chemical Composition**

5.1 All fasteners shall be made from alloy steel conforming to the chemical composition requirements in accordance with Table 1. The steel shall contain sufficient alloying elements to qualify it as an alloy steel.

**Note 5**—Steel is considered to be alloy, by the American Iron and Steel Institute, when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: manganese, 1.65 %; silicon, 0.60 %; copper, 0.60 %; or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99 %, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying elements added to obtain a desired alloying effect.

5.2 Product analysis may be made by the purchaser from finished material representing each lot of fasteners. The chemical composition thus determined shall conform to the requirements given in Table 1. Choice of alloy steel composition necessary to ensure meeting the specified mechanical requirements shall be made by the manufacturer and shall be reported to the purchaser for information purposes only.

5.3 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

5.4 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. **Mechanical Properties**

6.1 Fasteners shall not exceed the maximum hardness specified in Table 2. Fasteners less than three diameters in length and studs less than four diameters in length shall have hardness values not less than the minimum nor more than the maximum hardness limits required in Table 2, as hardness is the only requirement.

6.2 Fasteners 1 3/4 in. in diameter or less for Grade BC and 1 1/4 in. in diameter or less for Grade BD, other than those excepted in 6.1, shall be tested full size and shall conform to the tensile strength and either the proof load or the yield strength requirements in accordance with Table 3.

<table>
<thead>
<tr>
<th>TABLE 1 Chemical Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element</td>
</tr>
<tr>
<td>Carbon:</td>
</tr>
<tr>
<td>For sizes through 1 1/2 in.</td>
</tr>
<tr>
<td>For sizes through 1 1/2 in.</td>
</tr>
<tr>
<td>For sizes larger than 1 1/2 in.</td>
</tr>
<tr>
<td>Phosphorus, max</td>
</tr>
<tr>
<td>Sulfur, max</td>
</tr>
</tbody>
</table>
6.3 Fasteners larger than 1 3/8 in. in diameter for Grade BC and fasteners larger than 1 1/4 in. in diameter for Grade BD, other than those excepted in 6.1, shall preferably be tested full size and when so tested, shall conform to the tensile strength and either the proof load or yield strength requirements in accordance with Table 3 or Table 4. When equipment of sufficient capacity for full-size testing is not available, or when the length of the fastener makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements in accordance with Table 5. In the event that fasteners are tested by both full-size and by the machined test specimen methods, the full-size test shall govern if a controversy between the two methods exists.

6.4 For fasteners on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event that there is controversy over low readings of hardness tests.

7. Dimensions

7.1 Bolts—Unless otherwise specified, the bolts shall be Hex Head with dimensions conforming to the latest issue of ASME B18.2.1.

7.2 Studs—Studs shall have dimensions conforming to those specified by the purchaser.

7.3 Threads:

7.3.1 Unless otherwise specified, threads shall be the Unified National Coarse Thread Series as specified in ANSI B1.1, and shall have Class 2A tolerances.

7.3.2 When specified, threads shall be the Unified National Fine Thread Series, 8-Pitch Thread Series for sizes over 1 in. or 14-Pitch UNS on 1 in. size as specified in ANSI B1.1 and shall have Class 2A tolerances.

7.3.3 Unless otherwise specified, bolts and studs to be used with nuts or tapped holes that have been tapped oversize, in accordance with Specification A 563, shall have Class 2A threads before hot dip or mechanically deposited zinc coating. After zinc coating, the maximum limit of pitch and major diameter may exceed the Class 2A limit by the following amount:

<table>
<thead>
<tr>
<th>Diameter, in.</th>
<th>Oversize Limit, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4</td>
<td>0.016</td>
</tr>
<tr>
<td>5/32, 3/16</td>
<td>0.017</td>
</tr>
<tr>
<td>7/32, 1/4</td>
<td>0.018</td>
</tr>
<tr>
<td>9/32 to 5/16, incl</td>
<td>0.020</td>
</tr>
<tr>
<td>5/32</td>
<td>0.022</td>
</tr>
<tr>
<td>1.0 to 1 1/4, incl</td>
<td>0.024</td>
</tr>
<tr>
<td>1 1/4, 1 1/2</td>
<td>0.027</td>
</tr>
<tr>
<td>1 1/4 to 4.0, incl</td>
<td>0.050</td>
</tr>
</tbody>
</table>

These values are the same as the overtapping required for zinc-coated nuts in Specification A 563.

8. Workmanship

8.1 Surface discontinuity limits shall be in accordance with Specification F 788/F 788M.

9. Number of Tests

9.1 Testing Responsibility:

9.1.1 Each lot shall be tested by the manufacturer prior to shipment in accordance with the lot identification control quality assurance plan in 9.2 through 9.6.

9.1.2 When fasteners are furnished by a source other than the manufacturer, the responsible party as defined in 12.1 shall be responsible for ensuring that all tests have been performed and the fasteners comply with the requirements of this specification.

9.2 Purpose of Lot Inspection—The purpose of a lot inspection program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective it is essential that secondary processors, distributors, and purchasers maintain the identification and integrity of each lot until the product is installed.

9.3 Lot Processing—All fasteners shall be processed in accordance with a lot identification-control quality assurance plan. The manufacturer, secondary processors, and distributors shall identify and maintain the integrity of each lot of fasteners from raw-material selection through all processing operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

9.4 Lot Definition—A lot is a quantity of a uniquely identified fastener product of the same nominal size and length produced consecutively at the initial operation from a single mill heat of material and heat treatment lot and processed at one time, by the
### TABLE 3  Tensile Requirements for All Full-Size Fasteners—Inch-Pound Units

<table>
<thead>
<tr>
<th>Bolt Size, in.</th>
<th>Threads per inch</th>
<th>Stress Area, in.²</th>
<th>Grade BC</th>
<th>Grade BD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tensile Strength, min, lbf</td>
<td>Proof Load, min, lbf</td>
</tr>
<tr>
<td>1/4</td>
<td>20</td>
<td>0.0318</td>
<td>4 000</td>
<td>3 350</td>
</tr>
<tr>
<td>1/4</td>
<td>28</td>
<td>0.0364</td>
<td>4 550</td>
<td>3 820</td>
</tr>
<tr>
<td>5/32</td>
<td>18</td>
<td>0.0524</td>
<td>6 550</td>
<td>5 500</td>
</tr>
<tr>
<td>3/32</td>
<td>24</td>
<td>0.0680</td>
<td>7 250</td>
<td>6 200</td>
</tr>
<tr>
<td>3/32</td>
<td>16</td>
<td>0.0775</td>
<td>9 700</td>
<td>8 150</td>
</tr>
<tr>
<td>5/32</td>
<td>24</td>
<td>0.0878</td>
<td>11 000</td>
<td>9 220</td>
</tr>
<tr>
<td>3/16</td>
<td>14</td>
<td>0.1063</td>
<td>13 300</td>
<td>11 150</td>
</tr>
<tr>
<td>3/16</td>
<td>20</td>
<td>0.1187</td>
<td>14 940</td>
<td>12 470</td>
</tr>
<tr>
<td>1/2</td>
<td>13</td>
<td>0.1419</td>
<td>17 750</td>
<td>14 900</td>
</tr>
<tr>
<td>7/32</td>
<td>20</td>
<td>0.1599</td>
<td>19 990</td>
<td>17 690</td>
</tr>
<tr>
<td>5/32</td>
<td>18</td>
<td>0.1822</td>
<td>22 750</td>
<td>19 100</td>
</tr>
<tr>
<td>3/16</td>
<td>11</td>
<td>0.2262</td>
<td>28 250</td>
<td>23 750</td>
</tr>
<tr>
<td>5/32</td>
<td>18</td>
<td>0.2566</td>
<td>32 000</td>
<td>26 800</td>
</tr>
<tr>
<td>3/16</td>
<td>14</td>
<td>0.3344</td>
<td>41 750</td>
<td>35 050</td>
</tr>
<tr>
<td>1/2</td>
<td>16</td>
<td>0.3738</td>
<td>46 600</td>
<td>39 100</td>
</tr>
<tr>
<td>7/32</td>
<td>9</td>
<td>0.4627</td>
<td>57 750</td>
<td>48 500</td>
</tr>
<tr>
<td>5/32</td>
<td>14</td>
<td>0.5099</td>
<td>63 600</td>
<td>53 400</td>
</tr>
</tbody>
</table>

**Notes:**
- Stress Area, in.² = 0.7854 \(D - 0.9743/n\)² where \(D\) = nominal diameter, in., and \(n\) = threads/in.
- Based on 125 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 115 000 psi for sizes over 2 1/2 to 4 in., inclusive.
- Based on 105 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 95 000 psi for sizes over 2 1/2 to 4 in., inclusive.
- Based on 109 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 99 000 psi for sizes over 2 1/2 to 4 in., inclusive.
- Based on 150 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 140 000 psi for sizes over 2 1/2 to 4 in., inclusive.
- Based on 120 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 105 000 psi for sizes over 2 1/2 to 4 in., inclusive.
- Stress Area, in.² = 0.7854 \(D - 0.9743/n\)² where \(D\) = nominal diameter, in., and \(n\) = threads/in.
<table>
<thead>
<tr>
<th>Bolt Size, in.</th>
<th>Threads per inch</th>
<th>Stress Area, (A) mm²</th>
<th>Tensile Strength, min, kN</th>
<th>Proof Load, min, kN</th>
<th>Yield Strength, (0.2 % offset), min, kN</th>
<th>Tensile Strength, min, kN</th>
<th>Proof Load, min, kN</th>
<th>Yield Strength, (0.2 % offset), min, kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\frac{3}{4})</td>
<td>20</td>
<td>20.5</td>
<td>17.7</td>
<td>14.9</td>
<td>15.4</td>
<td>21.2</td>
<td>17.0</td>
<td>18.4</td>
</tr>
<tr>
<td>(\frac{1}{2})</td>
<td>24</td>
<td>23.5</td>
<td>20.2</td>
<td>17.0</td>
<td>17.7</td>
<td>24.3</td>
<td>19.4</td>
<td>21.1</td>
</tr>
<tr>
<td>(\frac{5}{16})</td>
<td>18</td>
<td>33.8</td>
<td>29.1</td>
<td>24.5</td>
<td>25.6</td>
<td>30.0</td>
<td>28.0</td>
<td>30.3</td>
</tr>
<tr>
<td>(\frac{5}{32})</td>
<td>24</td>
<td>37.4</td>
<td>32.2</td>
<td>27.1</td>
<td>28.1</td>
<td>38.7</td>
<td>30.9</td>
<td>33.5</td>
</tr>
<tr>
<td>(\frac{5}{64})</td>
<td>16</td>
<td>50.0</td>
<td>43.1</td>
<td>36.2</td>
<td>37.6</td>
<td>51.7</td>
<td>41.4</td>
<td>44.8</td>
</tr>
<tr>
<td>(\frac{1}{8})</td>
<td>24</td>
<td>56.6</td>
<td>48.8</td>
<td>41.0</td>
<td>42.6</td>
<td>58.5</td>
<td>46.8</td>
<td>50.7</td>
</tr>
<tr>
<td>(\frac{1}{16})</td>
<td>14</td>
<td>68.6</td>
<td>59.1</td>
<td>49.6</td>
<td>51.5</td>
<td>70.9</td>
<td>56.7</td>
<td>61.5</td>
</tr>
<tr>
<td>(\frac{1}{32})</td>
<td>20</td>
<td>76.6</td>
<td>66.0</td>
<td>55.5</td>
<td>57.6</td>
<td>79.2</td>
<td>63.3</td>
<td>68.6</td>
</tr>
<tr>
<td>(\frac{1}{4})</td>
<td>13</td>
<td>91.5</td>
<td>78.9</td>
<td>66.3</td>
<td>68.8</td>
<td>94.7</td>
<td>75.7</td>
<td>82.1</td>
</tr>
<tr>
<td>(\frac{3}{32})</td>
<td>20</td>
<td>103</td>
<td>88.8</td>
<td>74.6</td>
<td>77.5</td>
<td>106.5</td>
<td>85.2</td>
<td>92.3</td>
</tr>
<tr>
<td>(\frac{3}{64})</td>
<td>12</td>
<td>111</td>
<td>101.2</td>
<td>85.0</td>
<td>88.2</td>
<td>121.4</td>
<td>97.1</td>
<td>105.2</td>
</tr>
<tr>
<td>(\frac{1}{16})</td>
<td>18</td>
<td>131</td>
<td>112.0</td>
<td>94.8</td>
<td>98.5</td>
<td>135.4</td>
<td>108.3</td>
<td>117.4</td>
</tr>
<tr>
<td>(\frac{1}{32})</td>
<td>11</td>
<td>145</td>
<td>125.7</td>
<td>105.6</td>
<td>109.6</td>
<td>150.6</td>
<td>120.6</td>
<td>130.7</td>
</tr>
<tr>
<td>(\frac{1}{64})</td>
<td>18</td>
<td>165</td>
<td>142.2</td>
<td>119.5</td>
<td>124.1</td>
<td>170.6</td>
<td>136.5</td>
<td>147.8</td>
</tr>
<tr>
<td>(\frac{1}{96})</td>
<td>10</td>
<td>215</td>
<td>185.7</td>
<td>156.0</td>
<td>161.9</td>
<td>222.9</td>
<td>178.3</td>
<td>193.1</td>
</tr>
<tr>
<td>(\frac{1}{192})</td>
<td>16</td>
<td>241</td>
<td>207.7</td>
<td>174.5</td>
<td>181.2</td>
<td>249.2</td>
<td>199.3</td>
<td>215.9</td>
</tr>
<tr>
<td>(\frac{1}{384})</td>
<td>9</td>
<td>298</td>
<td>320.0</td>
<td>215.8</td>
<td>224.0</td>
<td>308.3</td>
<td>246.8</td>
<td>269.2</td>
</tr>
<tr>
<td>(\frac{1}{768})</td>
<td>14</td>
<td>328</td>
<td>282.3</td>
<td>237.5</td>
<td>246.6</td>
<td>339.2</td>
<td>271.3</td>
<td>293.9</td>
</tr>
</tbody>
</table>

**Table 4** Tensile Requirements for All Full-Size Fasteners—SI Units

---

\[^A\] Stress Area, \(A\) mm² = 0.7854 \((D - 0.9382 P)\)^2, where \(D\) is nominal product size, mm, and \(P\) is thread pitch, mm.

\[^B\] Based on 862 MPa for sizes \(\frac{1}{4}\) to \(\frac{1}{2}\) in., inclusive, and on 793 MPa for sizes over \(\frac{1}{2}\) to 4 in., inclusive.

\[^C\] Based on 724 MPa for sizes \(\frac{1}{4}\) to \(\frac{1}{2}\) in., inclusive, and on 655 MPa for sizes over \(\frac{1}{2}\) to 4 in., inclusive.

\[^D\] Based on 752 MPa for sizes \(\frac{1}{4}\) to \(\frac{1}{2}\) in., inclusive, and on 683 MPa for sizes over \(\frac{1}{2}\) to 4 in., inclusive.

\[^E\] Based on 1034 MPa for sizes \(\frac{1}{4}\) to \(\frac{1}{2}\) in., inclusive, and on 955 MPa for sizes over \(\frac{1}{2}\) to 4 in., inclusive.

\[^F\] Based on 827 MPa for sizes \(\frac{1}{4}\) to \(\frac{1}{2}\) in., inclusive, and on 742 MPa for sizes over \(\frac{1}{2}\) to 4 in., inclusive.

\[^G\] Based on 896 MPa for sizes \(\frac{1}{4}\) to \(\frac{1}{2}\) in., inclusive, and on 793 MPa for sizes over \(\frac{1}{2}\) to 4 in., inclusive.
same process, in the same manner so that statistical sampling is valid. The identity of the lot is maintained throughout all subsequent operations and packaging.

9.5 **Number of Tests**—The minimum number of tests from each production lot for the tests specified below shall be in accordance with Guide F 1470.

<table>
<thead>
<tr>
<th>Hardness Coating Weight/Thickness</th>
<th>Tensile Workmanship (Surface Discontinuities Section 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proof Load</td>
<td></td>
</tr>
</tbody>
</table>

9.5.1 The number of tests for dimensional and thread fit compliance shall be in accordance with the quality assurance provisions of the referenced dimensional standards.

9.6 If any test specimen shows defective machining it may be discarded and another specimen substituted.

10. **Test Methods**

10.1 Test methods shall be conducted in accordance with Test Methods F 606.

10.2 Proof load, rather than yield strength determination is preferred and shall be the arbitration method for fasteners 1 1/4 in. and under in diameter.

10.3 Hexagon bolts shall be tested by the wedge tension method. Fracture shall be in the body or threads of the bolt without any fracture at the junction of the head and body.

10.3.1 At the option of the manufacturer, the yield strength test (Method 2, Yield Strength paragraph of Test Methods F 606) and the wedge tension test (Wedge Tension Testing of Full-Size Product paragraph, both from the Test Method section of Test Methods F 606) may be accomplished concurrently to satisfy 10.2 and 10.3.

10.4 Studs and bolts other than those in 10.3 shall be tested by the axial tension method.

10.4.1 At the option of the manufacturer, the yield strength test and the axial tension test may be accomplished concurrently to satisfy 10.2 and 10.4.

10.5 The speed of testing determined with a free running crosshead shall be a maximum of 1/8 in. (3.2 mm)/min for the bolt proof load (or yield strength) determination and a maximum of 1 in. (25.4 mm)/min for the tensile strength determination.

11. **Inspection**

11.1 If the inspection described in 11.2 is required by the purchaser, it shall be specified in the inquiry and contract or purchase order.

11.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser’s representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

12. **Responsibility**

12.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested, and inspected in accordance with this specification and meets all of its requirements.

13. **Rejection and Rehearing**

13.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

14. **Certification**

14.1 When specified on the purchase order, the manufacturer or supplier, whichever is the responsible party in accordance with Section 12, shall furnish the purchaser a test report which includes the following:

---

**TABLE 5 Mechanical Requirements for Machined Specimens**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Size, in.</th>
<th>Tensile Strength</th>
<th>Yield Strength</th>
<th>Elongation in 2 in. or 50 mm</th>
<th>Reduction of Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>min, psi (MPa)</td>
<td>min, psi (MPa)</td>
<td>min, %</td>
<td>min, %</td>
</tr>
<tr>
<td>BC</td>
<td>1/4 to 2 1/2, incl</td>
<td>125 000 (862)</td>
<td>109 000 (752)</td>
<td>16</td>
<td>50</td>
</tr>
<tr>
<td>BC</td>
<td>Over 2 1/2</td>
<td>115 000 (793)</td>
<td>99 000 (683)</td>
<td>16</td>
<td>45</td>
</tr>
<tr>
<td>BD</td>
<td>1/4 to 2 1/2, incl</td>
<td>150 000 (1034)</td>
<td>130 000 (896)</td>
<td>14</td>
<td>40</td>
</tr>
<tr>
<td>BD</td>
<td>Over 2 1/2</td>
<td>140 000 (965)</td>
<td>115 000 (793)</td>
<td>14</td>
<td>40</td>
</tr>
</tbody>
</table>
14.1.1 Product description, grade, quantity, ASTM Specification Number and issue date,
14.1.2 Alloy grade (AISI, SAE, UNS, etc.), heat analysis, and heat number, and type of quench,
14.1.3 Results of hardness, tensile, and proof load tests, as applicable,
14.1.4 Statement of compliance to Protective Coating Specification (if applicable),
14.1.5 Statement of compliance with the surface discontinuity requirements of Specification F 788/F 788M,
14.1.6 Statement of compliance dimensionally,
14.1.7 Report, describe, or illustrate manufacturer’s markings and their location,
14.1.8 Lot number, purchase order number, and date shipped,
14.1.9 Country of origin, and
14.1.10 Title and signature of the individual assigned certification responsibility by the company officers, with complete mailing
address.
14.2 Failure to include all the required information on the test report shall be cause for rejection.

15. Product Marking
15.1 Manufacturers Identification —All products shall be marked by the manufacturer with a unique identifier to identify the
manufacturer or private label distributor, as appropriate.
15.2 Grade Identification:
15.2.1 All Grade BC products shall be marked “BC”.
15.2.2 All Grade BD products shall be marked “BD”. In addition to the “BD” marking, the product may be marked with 6 radial
lines 60° apart if manufactured from alloy steel conforming to the requirements of this specification.
15.2.3 Grade BD product in stock marked to the requirements of the —95 issue, shall be considered acceptable until October
1, 1999, to allow disposition of existing stock.
15.3 Marking Location and Methods:
15.3.1 Bolts shall be marked on the top of the bolt head.
15.3.2 Where studs have both coarse and fine threads, all markings shall appear on the coarse thread end or, if preferred, the
manufacturer’s identification shall appear on the fine thread end and the grade marking on the coarse thread end.
15.3.3 Continuous thread studs may be marked on either end.
15.3.4 All markings may be raised or depressed at the manufacturer’s option.
15.3.5 Grade and manufacturer’s or private label distributor’s identification shall be separate and distinct. The two
identifications shall preferably be in different locations and when on the same level shall be separated by at least two spaces.

16. Packaging and Package Marking
16.1 Packaging:
16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.
16.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.
16.2 Package Marking:
16.2.1 Each shipping unit shall include or be plainly marked with the following information:
16.2.1.1 ASTM designation and grade,
16.2.1.2 Size,
16.2.1.3 Name and brand or trademark of the manufacturer,
16.2.1.4 Number of pieces,
16.2.1.5 Purchase order number, and
16.2.1.6 Country of origin.

17. Keywords
17.1 alloy steel; bolts; steel; studs
S1. Marking

S1.1 Studs that are continuously threaded with the same class of thread shall be marked on each end with the marking in accordance with Section 15.

S1.2 Marking small sizes (customarily less than 0.375 in. (9.525 mm) may not be practical. Consult the producer for the minimum size that can be marked.

SUMMARY OF CHANGES

This section identifies the location of selected changes to this specification that have been incorporated since the A 354 - 013 issue. For the convenience of the user, Committee F16 has highlighted those changes that may impact the use of this specification. This section may also include descriptions of the changes or reasons for the changes, or both. (Approved Oct. 1, 2003).

(1) Added Section 1.5 that references Terminology F 1789 for definitions of terms.

This section identifies the location of selected changes to this specification that have been incorporated since the A 354 - 01 issue. For the convenience of the user, Committee F16 has highlighted those changes that may impact the use of this specification. This section may also include descriptions of the changes or reasons for the changes, or both. (Approved March 10, 2003.)

(1) Section 14.1.4 was revised to delete reporting the baking time and temperature and stating “Not Baked” when not baked.
Standard Specification for Steel Transmission Tower Bolts, Zinc-Coated and Bare

This standard is issued under the fixed designation A 394; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This specification covers the chemical and mechanical requirements of hexagon and square-head zinc-coated steel bolts and atmospheric corrosion-resistant bolts, in nominal thread diameters of 1/2, 5/8, 3/4, 7/8 and 1 in. for use in the construction of transmission towers, substations, and similar steel structures. The various types of bolts covered in this specification are:

1.1.1 Type 0—Zinc-coated bolts made of low or medium carbon steel.

1.1.2 Type 1—Zinc-coated bolts made of medium carbon steel, quenched and tempered.

1.1.3 Type 2—Zinc-coated bolts made from what is generally described as low-carbon martensite steel, quenched and tempered.

1.1.4 Type 3—Bare (uncoated), quenched and tempered bolts made of steel having atmospheric corrosion-resistance and weathering characteristics comparable to that of the steel covered in Specifications A 242/A 242M, A 588/A 588M, and A 709/A 709M. The atmospheric corrosion resistance of these steels is substantially better than that of carbon steel with or without copper addition (see 5.4). When properly exposed to the atmosphere, these steels can be used bare (uncoated) for many applications.

1.1.5 For applications requiring improved low-temperature characteristics, use of Types 1, 2, or 3 bolts is recommended.

1.2 Annex A1 of this specification covers zinc-coated steel ladder bolts, step bolts, and support-equipment bolts.

1.3 Unless otherwise specified, all nuts used on these bolts shall be hex style and conform to the requirements of Specification A 563 as follows:

<table>
<thead>
<tr>
<th>Bolt Type</th>
<th>Nut Grade</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>A</td>
<td>Zinc-coated</td>
</tr>
<tr>
<td>1 and 2</td>
<td>DH</td>
<td>Zinc-coated</td>
</tr>
<tr>
<td>3</td>
<td>DH3</td>
<td>Plain</td>
</tr>
</tbody>
</table>

1.4 Suitable washers for use with Type 0 are zinc-coated carbon-steel washers with dimensions that are in accordance with Specification F 436. Suitable washers for use with Type 1 and Type 2 bolts are zinc-coated Type 1 hardened-steel washers that are in accordance with Specification F 436. Suitable washers for use with Type 3 bolts are Type 3 hardened-steel washers that are in accordance with Specification F 436.

1.5 Nuts and washers that are supplied under this specification that are zinc coated shall be in accordance with 4.4.

1.6 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:

A 90 Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A 242/A 242M Specification for High-Strength Low-Alloy Structural Steel

A 563 Specification for Carbon and Alloy Steel Nuts

A 588/A 588M Specification for High-Strength Low-Alloy Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4 in. [100 mm] Thick

A 709/A 709M Specification for Structural Steel for Bridges

B 6 Specification for Zinc (Slab Zinc)

B 244 Test Method for Measurement of Thickness of Anodic Coatings on Aluminum and of Other Nonconductive Coatings on Nonmagnetic Basis Metals with Eddy-Current Instruments


B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel

D 3951 Practice for Commercial Packaging

F 436 Specification for Hardened Steel Washers

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners

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1 This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.02 on Steel Bolts, Nuts, Rivets, and Washers.


* A Summary of Changes section appears at the end of this standard.
Washers, and Rivets\(^4\)
F 788/F 788M Specification for Surface Discontinuities of bolts, Screws, and Studs, Inch and Metric Series\(^4\)
G 101 Guide for Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steels\(^8\)

2.2 ANSI/ASME Standards:
B1.1 Unified Screw Threads\(^9\)
B18.2.1 Square and Hex Bolts and Screws\(^9\)
B 18.24.1 Part Identifying Number (PIN) Code System\(^10\)

2.3 Military Standard:
MIL-STD-105 Single Sampling Plan for Normal Inspection\(^11\)

3. Ordering Information

3.1 Orders for products under this specification shall include the following:

3.1.1 Quantity (number of bolts and accessories).
3.1.2 Name of products, including accessories such as A 563 nuts and F 436 washers when desired.
3.1.3 Dimensions, including nominal bolt diameter and length. For bolts other than transmission-tower bolts, complete dimensions are required (see Annex A1).
3.1.4 Type of bolt (for example, Type 0, 1, 2, or 3).
3.1.4.1 When non-zinc-coated atmospheric corrosion-resistant steel is required, Type 3 bolts shall be specified by the purchaser.
3.1.5 For Type 0 and Type 1 bolts specify the zinc-coating process required, such as, “hot dip,” “mechanically deposited,” or “no preference.” Type 2 bolts shall have only mechanically-deposited zinc coatings.
3.1.6 ASTM designation and year of issue. When year of issue is not specified, bolts shall be furnished to the latest issue.
3.1.7 Additional requirements, if any, are to be specified on the purchase order:
3.1.7.1 Shear-strength testing (see 6.2.1 and 6.2.2). Include type of test required.
3.1.7.2 Additional tests (see 10.2).
3.1.7.3 Inspection (see 12.1 and 12.2).
3.1.7.4 Certification (see 14.1).
3.1.7.5 Test reports (see 14.2).

Note 1—Examples of ordering description:
(1) 1000 square-head transmission-tower bolts, ½ by 2 in. Type 1, hot dip zinc coated, shear testing required, ASTM A 394 – XX, with hot-dip zinc-coated hex nuts, Grade DH, ASTM A 563 – XX.
(2) 1000 transmission tower bolts, ½ by 2 in. Type 0, mechanically zinc coated, ASTM A 394 – XX, with mechanically zinc-coated hex nuts, Grade A, ASTM A 563 – XX.
(3) 1000 transmission tower bolts, ½ by 2 in. Type 3, Supplementary Requirement S2, ASTM A 394 – XX, with hex nuts, Grade DH3 weathering steel, ASTM A 563 – XX and with 2 circular washers, Type 3, ASTM F 436 – XX.

3.1.8 For establishment of a part identifying system, see ASME B18.24.1.

4. Materials and Manufacture

4.1 Steel for the manufacture of bolts shall be made by any of the following processes: open-hearth, electric-furnace, or basic-oxygen.

4.1.1 Cold-headed Type 0 bolts shall be stress relieved annealed before zinc coating to remove cold work effects such that hardness measured anywhere on the surface or through the cross section shall meet the requirements in 6.1.
4.2 Types 1, 2 and 3 bolts shall be heat treated by quenching in a suitable liquid medium from above the austenitizing temperature and then tempering to the required finished hardness.
4.3 Slab zinc when used for coating shall be any grade of zinc conforming to Specification B 6.
4.4 Zinc Coatings, Hot Dip and Mechanically Deposited.
4.4.1 Type 0 and Type 1 bolts shall be zinc coated. The purchaser shall specify the zinc-coating process, that is “hot dip,” “mechanically deposited,” or “no preference.”
4.4.2 Type 2 bolts shall be zinc coated by the mechanical-deposition process.
4.4.3 When “hot dip” is specified, the bolts shall be zinc coated by the hot-dip process in accordance with the requirements of Class C of Specification A 153, except as specified in 4.4.6.
4.4.4 When “mechanically deposited” is specified, the bolts shall be zinc coated by the mechanical-deposition process in accordance with the requirements of Class 50 of Specification B 695, except as specified in 4.4.6.
4.4.5 When “no preference” is specified, the supplier may furnish either a hot-dip zinc-coating in accordance with Specification A 153 Class C, or a mechanically deposited zinc-coating in accordance with Specification B 695 Class 50, except as specified in 4.4.6. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process and the supplier’s option is limited to one process per item with no mixed processes in a lot.
4.4.6 The minimum average weight of a zinc coating shall be 1.65 oz/ft\(^2\). The minimum weight of a zinc coating on any one item shall be 1.50 oz/ft\(^2\).
4.4.7 Bolt threads shall not be cut, rolled, or otherwise finished after galvanizing.
4.4.8 Hot-dip zinc-coated nuts furnished under Specification A 563 shall be tapped after galvanizing.

5. Chemical Composition

5.1 Type 0 bolts shall conform to the chemical composition requirements specified for low-carbon steel bolts outlined in Table 1.
5.2 Type 1 bolts shall conform to the chemical composition requirements specified for medium carbon steel bolts in Table 1.
5.3 Type 2 bolts shall conform to the chemical composition requirements specified for low-carbon martensite steel bolts in Table 1.
5.4 Type 3 bolts shall conform to one of the chemical compositions specified in Table 2. The selection of the chemical composition A, B, C, D, E, or F shall be at the option of the bolt manufacturer. See Guide G 101 for methods of estimating the atmospheric corrosion resistance of low alloy steels.

5.5 Bolts are customarily furnished from stock and individual heats of steel cannot be identified.

6. Mechanical Properties

6.1 Tension Test—Types 0, 1, 2, and 3 bolts having a length equal to or more than 3 diameters shall be wedge tension tested as specified in 11.1 and shall conform to the tensile stress requirements in Table 3. Zinc-coated bolts shall be tested after coating. Bolts too short for full size testing or for other reasons not subject to tension tests, shall meet the following hardness requirements:

<table>
<thead>
<tr>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>25</td>
<td>34</td>
</tr>
</tbody>
</table>

6.2 Shear Strength:

6.2.1 When specified in the original inquiry and order, bolts, except as excluded in 6.2.2, shall be shear strength tested in accordance with 11.2 and shall meet the requirements given in Table 4.

6.2.2 Bolts with unthreaded body lengths shorter than two times the nominal bolt diameter, are subject to shear strength testing only upon agreement between the purchaser and supplier as to testing method and shear strength values.

7. Dimensions

7.1 Bolt threads, before zinc coating, shall be the unified coarse thread series and Class 2A tolerance as defined in the latest issue of ANSI/ASME B1.1. Threads may be rolled or cut.

7.2 Bolts shall be full-size body in conformance with the latest issue of ANSI/ASME B18.2.1, except that the full-body length listed in Table 5 shall be the basis of manufacture and inspection. Unless otherwise specified, hex bolts shall be furnished. Ends of bolts need not be chamfered or pointed.

7.3 Zinc-coated bolts must assemble with a nut tapped oversize as described in Specification A 563. In case of dispute, a calibrated go and not go thread-ring gage of the same diameter, thread class, and tolerance plus the amount of

---

### TABLE 1 Chemical Requirements and Head Markings

<table>
<thead>
<tr>
<th>Head Marking</th>
<th>Bolt Type</th>
<th>Element, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Carbon</td>
</tr>
<tr>
<td>T0</td>
<td>0</td>
<td>0.55 max</td>
</tr>
<tr>
<td>T1</td>
<td>1</td>
<td>0.28/0.55</td>
</tr>
<tr>
<td>T2</td>
<td>2</td>
<td>0.15/0.25</td>
</tr>
<tr>
<td>T3</td>
<td>3</td>
<td>...</td>
</tr>
</tbody>
</table>

5.4 Type 3 bolts shall conform to one of the chemical compositions specified in Table 2. The selection of the chemical composition A, B, C, D, E, or F shall be at the option of the bolt manufacturer. See Guide G 101 for methods of estimating the atmospheric corrosion resistance of low alloy steels.

5.5 Bolts are customarily furnished from stock and individual heats of steel cannot be identified.

### TABLE 2 Chemical Requirements for Type 3 Bolts

| Element Product Analysis | Type 3 Bolts Composition, %  
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Carbon</td>
<td>0.31–0.42</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.86–1.24</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.045 max</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.055 max</td>
</tr>
<tr>
<td>Silicon</td>
<td>0.13–0.32</td>
</tr>
<tr>
<td>Copper</td>
<td>0.22–0.48</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.22–0.48</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.42–0.88</td>
</tr>
<tr>
<td>Vanadium</td>
<td>...</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>...</td>
</tr>
<tr>
<td>Titanium</td>
<td>...</td>
</tr>
</tbody>
</table>

### TABLE 3 Tensile Strength

<table>
<thead>
<tr>
<th>Nominal Size, in.</th>
<th>Type 0, Tensile Strength, lbf</th>
<th>Types 1, 2, and 3, Tensile Strength, lbf</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>10 500</td>
<td>17 050</td>
</tr>
<tr>
<td>5/8</td>
<td>16 700</td>
<td>27 100</td>
</tr>
<tr>
<td>3/4</td>
<td>24 700</td>
<td>40 100</td>
</tr>
<tr>
<td>7/8</td>
<td>34 200</td>
<td>55 450</td>
</tr>
<tr>
<td>1</td>
<td>44 850</td>
<td>72 700</td>
</tr>
</tbody>
</table>

* A tensile strength based on the thread stress area, As, is calculated as follows: 

\[ A_s = 0.7854 \left( \frac{D}{D - (0.9743/N)^2} \right) \]

where:

- \( D \) = nominal diameter, and
- \( N \) = threads per inch.

T0 Based on 74 000 psi unit tensile strength.

T1 Based on 120 000 psi unit tensile strength.

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A, B, C, D, E, and F are classes of material used for Type 3 bolts. Selection of a class shall be at the option of the bolt manufacturer.
overtap shall be used. Assembly of the gage, or the nut described above, shall be possible with hand effort following application of light machine oil to prevent galling and damage to the gage. These inspections, when performed to resolve disputes, shall be performed at the frequency and acceptability specified in Table 6.

8. Workmanship

8.1 Surface discontinuity limits of Types 1, 2, and 3 shall be in accordance with Specification F 788/F 788M.

9. Sampling

9.1 Paragraphs 9.2 and 9.3 describe routine production tests performed by the fastener manufacturer. Identification of treatment lots is not retained after tests are performed and found to be acceptable. As described in 5.5, heats are not kept separate in stock and only the test reports described in 14.2 can be furnished.

9.2 Sample bolts shall be taken from each heat treatment or stress-relief-annealing lot and subjected to the required tests described in 6.1. Bolts that are not heat treated in any way are separate in stock and only the test reports described in 14.2 can be used. As described in 5.5, heats are not kept separate in stock and only the test reports described in 14.2 can be furnished.

9.3 Samples for tests of each lot of Types 0, 1, and 2 zinc-coated bolts shall be taken as specified in 10.3 and subjected to the tests described in 11.1. A lot shall be all bolts of the same type, head configuration, nominal thread diameter, length, and heat treated at the same time.

9.4 Samples for tests of each lot of Type 3 bolts shall be taken as specified in 10.3 and subjected to the tests described in 11.1. A lot shall be all bolts of the same head configuration, nominal thread diameter, length, and the same continuous production run not to exceed an 8-h duration.

10. Number of Tests and Retests

10.1 The requirements of this specification shall be met in continuous mass production for stock. Additional tests of individual shipments are not ordinarily contemplated.

10.2 When additional tests are specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all material offered for inspection at one time, of the same type, head configuration, nominal thread diameter, and length.

10.3 From each lot as described in Section 9, the number of samples for the mechanical tests and for the coating-thickness tests shall be in accordance with Table 7.

10.4 If the results of the mechanical tests of any test lot do not conform to the requirements because a flaw developed in the test specimen during testing, a retest shall be allowed. If the retest is satisfactory, the lot is acceptable.

11. Test Methods

11.1 Tests for hardness and tensile strength shall be conducted in accordance with Test Methods F 606. Bolts tested full size shall be tested using the wedge tension test. Fracture shall be in the threaded portion of the bolt without any fracture at the junction of the head and body.

11.2 Shear Test:

11.2.1 Bolts shall be single shear tested either through the unthreaded portion of the shank or through the threads as specified in the order. Holes in the shear plates shall be 1/16 in. larger than the nominal thread diameter of the test bolt and the holes shall be chamfered 1/16 in. to relieve sharp edges. Shear plates shall be prevented from separating by means of a suitable jig or by using a nut on the test bolt tightened finger tight.

11.2.2 Mount the test specimen in a tensile-testing machine capable of applying load at a controllable rate. Use self-aligning grips and take care when mounting the specimen to assure that the load will be transmitted in a straight line transversely through the test bolt. Apply load and continue until failure of the bolt. Speed of testing as determined with a free running cross head shall be no less than 1/4 in. nor greater than 1/2 in./min.

11.2.3 The maximum load applied to the specimen coincident with or prior to bolt failure, shall be recorded as the shear strength of the bolt.

11.2.4 Tests need not be continued to destruction provided that the specimen supports, without evidence of bolt failure, the minimum shear load specified in Table 4.

11.3 Weight and Thickness of Coating:

11.3.1 Weight of coating or thickness of coating shall be determined by the methods described in either 11.3.2 or 11.3.3 at the option of the manufacturer.

11.3.2 The weight of the coating for pieces whose areas can be readily calculated shall be determined by stripping the entire piece, or suitable representative section thereof, in accordance with the hydrochloric acid-antimony chloride method as described in Test Method A 90.

11.3.3 The thickness of coating may be determined by the use of a magnetic thickness gage. Several magnetic or electromagnetic types of thickness gages are commercially available and are satisfactory for inspection when properly calibrated just prior to inspection use as described in Test Methods B 499 and B 244, respectively. For purposes of conversions from coating thickness to weight of coating, 0.0025-in. coating thickness shall be considered to be equivalent to 1.5 oz/ft². The test for thickness of coating shall be made on a portion of the bolt that does not include any threads.
12. Inspection

12.1 If the inspection described in 12.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

12.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection required by the specification that are requested by the purchaser’s representative shall be made prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

13. Rejection and Rehearing

13.1 Bolts that fail to conform to the requirements of this specification may be rejected by the purchaser. Rejection shall be reported to the supplier promptly and in writing. In case of dissatisfaction with the results of tests or inspections authorized by the purchaser, the supplier may make claim for a rehearing.

14. Certification

14.1 When specified on the order, the manufacturer’s certification shall be furnished to the purchaser stating that the bolts were manufactured, sampled, tested, and inspected in accordance with this specification and have met the requirements.

14.2 When specified on the order, the manufacturer shall furnish the purchaser with a test report certifying to the last set of tests for each bolt type and size in the shipment.

15. Responsibility

15.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

16. Product Marking

16.1 Bolt heads shall be marked to identify the bolt type as specified in Table 1, the manufacturer or private label distributor, as appropriate, and the nominal length in inches and fractions.

16.2 The manufacturer may add additional distinguishing marks to the bolt head.

16.3 All markings shall be located on the top of the bolt head and may be raised or depressed at the option of the manufacturer.

16.4 Type and manufacturer’s or private label distributor’s identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

17. Packaging and Package Marking

17.1 Packaging:

17.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

17.1.2 When hot dip zinc-coated nuts and bolts are ordered together, they shall be shipped assembled unless otherwise specified.

17.1.3 When nuts and bolts are ordered together, they shall be shipped in the same container.

17.1.4 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

17.2 Package Marking:

17.2.1 Each shipping unit shall include or be plainly marked with the following information:

| Type and manufacturer’s or private label distributor’s identification shall be separate and distinct. | The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces. | Bolt heads shall be marked to identify the bolt type as specified in Table 1, the manufacturer or private label distributor, as appropriate, and the nominal length in inches and fractions. | 17.2.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951. | 17.1.2 When hot dip zinc-coated nuts and bolts are ordered together, they shall be shipped assembled unless otherwise specified. | 17.1.3 When nuts and bolts are ordered together, they shall be shipped in the same container. | 17.1.4 When special packaging requirements are required, they shall be defined at the time of the inquiry and order. | 17.2 Package Marking: | 17.2.1 Each shipping unit shall include or be plainly marked with the following information: | 17.2.1.1 ASTM designation and type, | 17.2.1.2 Size, | 17.2.1.3 Name and brand or trademark of the manufacturer, | 17.2.1.4 Number of pieces, | 17.2.1.5 Purchase order number, and | 17.2.1.6 Country of origin. | 5 | A 394 | TABLE 5 Length of Full Body for Bolts

<table>
<thead>
<tr>
<th>Length of Bolt, L, in.</th>
<th>Bolt Diameter, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{1}{2} )</td>
<td>( \frac{3}{8} )</td>
</tr>
<tr>
<td>( \frac{1}{2} )</td>
<td>( \frac{3}{8} )</td>
</tr>
<tr>
<td>( \frac{5}{8} )</td>
<td>( \frac{1}{2} )</td>
</tr>
<tr>
<td>( \frac{7}{8} )</td>
<td>( \frac{3}{4} )</td>
</tr>
<tr>
<td>( \frac{1}{2} )</td>
<td>( \frac{3}{4} )</td>
</tr>
</tbody>
</table>

TABLE 6 Sample Sizes and Acceptance Numbers for Inspection of Zinc-Coated Threads

<table>
<thead>
<tr>
<th>Lot Size</th>
<th>Sample Size</th>
<th>Acceptance Number</th>
<th>Rejection Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 90</td>
<td>13</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>91 to 150</td>
<td>20</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>151 to 280</td>
<td>32</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>281 to 500</td>
<td>50</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>501 to 1200</td>
<td>80</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>1201 to 3200</td>
<td>125</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>3201 to 10,000</td>
<td>200</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>10,001 and over</td>
<td>315</td>
<td>21</td>
<td>22</td>
</tr>
</tbody>
</table>

TABLE 7 Sample Sizes and Acceptance Numbers for Mechanical and Coating-Thickness Tests

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Mechanical Tests</th>
<th>Coating Tests</th>
<th>Acceptance Number</th>
<th>Rejection Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and under</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>801 to 8,000</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>8,001 to 35,000</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>35,001 to 150,000</td>
<td>8</td>
<td>5</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>150,001 and over</td>
<td>13</td>
<td>8</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
18. Keywords

18.1 bolts; carbon steel; steel; transmission tower; weathering steel

ANNEX

(Mandatory Information)

A1. LADDER BOLTS, STEP BOLTS, AND EQUIPMENT-SUPPORT BOLTS

A1.1 Dimensions of ladder bolts, step bolts, and equipment-support bolts shall be specified by the purchaser.

A1.2 Bolts shall be Type 0 unless otherwise agreed upon between the manufacturer and the purchaser.

A1.3 All other requirements relating to processing, properties, testing, and inspection shall be in accordance with Specification A 394.

SUMMARY OF CHANGES

This section identifies the location of selected changes to this standard that have been incorporated since the –93 issue. For the convenience of the user, Committee F16 has highlighted those changes that impact the use of this standard. This section may also include descriptions of the changes or reasons for the changes, or both.


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Standard Specification for Quenched and Tempered Steel Bolts and Studs

This standard is issued under the fixed designation A 449; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers the chemical and mechanical requirements for two types of quenched and tempered steel bolts and studs for general applications where high strength is required.

1.2 The two types of bolts covered in this specification are:

1.2.1 Type 1—Medium-carbon steel bolts and studs furnished in nominal diameters of 1/4 to 3 in., inclusive.

1.2.2 Type 2—Low-carbon martensite or medium-carbon martensite steel bolts and studs furnished in nominal diameters of 1/4 to 1 in., inclusive.

1.3 The bolts and studs shall be Type 1, Type 2, or Type 1 or 2 at manufacturer’s option, as specified by the purchaser. When a type is not specified, Type 1 shall be furnished. When elevated temperature applications are involved, Type 1 shall be specified by the purchaser on the order.

1.4 Suitable nuts are covered in Specification A 563. Unless otherwise specified, the grade and style of nut shall be as follows:

<table>
<thead>
<tr>
<th>Fastener Size and Surface Finish</th>
<th>Nut Grade and Style</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4 to 1 1/2 in., plain (or with a coating of insufficient thickness to require over-tapped nuts)</td>
<td>B, hex</td>
</tr>
<tr>
<td>Over 1 1/2 to 3 in., plain (or with a coating of insufficient thickness to require over-tapped nuts)</td>
<td>A, heavy hex</td>
</tr>
<tr>
<td>1/4 to 3 in., zinc-coated (or with a coating thickness requiring over-tapped nuts)</td>
<td>DH, heavy hex</td>
</tr>
</tbody>
</table>

Nuts of other grades and styles having specified proof load stresses (Specification A 563, Table 3) greater than the specified grade and style of nut are suitable.

1.5 Unless otherwise specified, washers ordered with bolts shall be furnished to the requirements of Specification F 436.

1.6 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

1.7 Terms used in this specification are defined in Terminology F 1789 unless otherwise defined herein.

2. Referenced Documents

2.1 ASTM Standards:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A 153/A 153M</td>
<td>Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware</td>
</tr>
<tr>
<td>A 563</td>
<td>Specification for Carbon and Alloy Steel Nuts</td>
</tr>
<tr>
<td>A 751</td>
<td>Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products</td>
</tr>
<tr>
<td>B 695</td>
<td>Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel</td>
</tr>
<tr>
<td>D 3951</td>
<td>Practice for Commercial Packaging</td>
</tr>
<tr>
<td>F 436</td>
<td>Specification for Hardened Steel Washers</td>
</tr>
<tr>
<td>F 606</td>
<td>Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets</td>
</tr>
<tr>
<td>F 788/F 788M</td>
<td>Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series</td>
</tr>
<tr>
<td>F 1789</td>
<td></td>
</tr>
<tr>
<td>B 1.1</td>
<td>Unified Screw Threads</td>
</tr>
<tr>
<td>B 18.2.1</td>
<td>Square and Hex Bolts and Screws</td>
</tr>
<tr>
<td></td>
<td>Part Identifying Number (PIN) Code System</td>
</tr>
</tbody>
</table>

3. Ordering Information

3.1 Orders for bolts and studs (including nuts and accessories) under this specification shall include the following:

3.1.1 ASTM designation and year of issue.

3.1.2 Type required, that is, Type 1, Type 2, or Type 1 or 2 at manufacturer’s option (see 1.3).

3.1.3 Name of product (that is, bolt or stud).

3.1.4 Quantities (number of pieces by size (including nuts)).

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*A Summary of Changes section appears at the end of this standard.

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3.1.5 Bolt size and length.
3.1.6 Washers—Specific quantity and size (separate from bolts).
3.1.7 Hot Dip or Mechanically Deposited Zinc Coatings—For hot dip or mechanically deposited zinc coatings covered by 5.1 and requiring overtapped nuts, specify the zinc coating process required, that is, hot dip, mechanically deposited, or no preference (see 5.1).
3.1.8 Other Coatings—Specify other protective coating if required (see 5.2).
3.1.9 Specify if inspection at point of manufacture is required.
3.1.10 Specify if certified test reports are required (see 10.2).
3.1.11 Specify additional testing (see 10.3) or special requirements.
3.1.12 Any special requirements.
3.1.13 For establishment of a part identifying system, see ASME B18.24.1.

4. Materials and Manufacture

4.1 Steel for bolts and studs shall be made by the open-hearth, basic-oxygen, or electric-furnace process.
4.2 Type 2 bolts and studs shall be made from fully killed fine-grain steel.
4.3 The bolts and studs shall be heat treated by quenching in a liquid medium from above the transformation temperature and then tempering by reheating to a temperature of not less than 800°F (425°C).
4.4 Threads of bolts and studs shall be rolled, cut, or ground.

5. Protective Coatings

5.1 Zinc, Hot Dip and Mechanically Deposited Requiring Overtapped Nuts:

5.1.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc-coating process, such as, hot dip, mechanically deposited, or no preference.
5.1.2 When hot dip is specified the fasteners shall be zinc coated by the hot-dip process in accordance with the requirements of Class C of Specification A 153.
5.1.3 When mechanically deposited is specified the fasteners shall be zinc coated by the mechanical-deposition process in accordance with the requirements of Class 50 of Specification B 695.
5.1.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification A 153, Class C, or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process, and the suppliers option shall be limited to one process per item with no mixed processes in a lot.
5.1.5 Type 2 bolts and studs shall be zinc coated by the mechanical-deposition process only.

NOTE 1—When the intended application requires that assembled tension exceeds 50 % of minimum bolt or stud proof load, an anti-galling lubricant may be needed. Application of such a lubricant to nuts and a test of the lubricant efficiency are provided in Supplementary Requirement S1 of Specification A 563 and should be specified when required.

5.2 Other Coatings:

5.2.1 Coatings other than specified in 5.1 shall be as specified by the purchaser on the purchase order.
5.2.2 When other coatings are specified, the complete specification for the coating shall be included as part of the purchase order.

6. Chemical Composition

6.1 The bolts and studs shall conform to the chemical composition specified in Table 1 for the type specified.
6.2 Product analyses may be made by the purchaser from finished material representing each lot. The chemical composition thus determined shall conform to the requirements prescribed for product analysis in Table 1.
6.3 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.
6.4 Chemical analyses shall be performed in accordance with Test Methods A 751.

7. Mechanical Properties

7.1 Bolts and studs shall not exceed the maximum hardness specified in Table 2.
7.2 Bolts less than three diameter in length and studs less than four diameter in length shall have hardness values not less than the minimum nor more than the maximum limits required by Table 2. This hardness testing is the only mechanical testing requirement for these bolts or studs.
7.3 Bolts and studs other than those excepted in 7.2 shall be subjected to tension tests as specified in 7.4 and 7.5.
7.4 Bolts and studs 1 1/2 in. in diameter or less, other than those excepted in 7.2, shall be tested full size and shall conform to the tensile strength and either the proof load or yield strength requirements specified in Tables 3 and 4.
7.5 Bolts and studs larger than 1 1/2 in. in diameter, other than those excepted in 7.2, shall preferably be tested full size and when so tested, shall conform to the tensile strength and either the proof load or yield strength requirements specified in Tables 3 and 4, respectively. When equipment of sufficient capacity for full-size testing is not available, or when the length

| Table 1 Chemical Requirements for Type 1 and Type 2 Bolts and Studs |
|------------------------|-----------------|-----------------|
| Element                | Composition, %  |
|                        | Type 1          | Type 2          |
| Carbon:                |                 |                 |
| Heat analysis          | 0.28–0.55       | 0.15–0.38       |
| Product analysis       | 0.25–0.58       | 0.13–0.41       |
| Manganese, min:        |                 |                 |
| Heat analysis          | 0.13–0.41       | 0.15–0.38       |
| Product analysis       | 0.048           | 0.048           |
| Phosphorus, max:       |                 |                 |
| Heat analysis          | 0.048           | 0.048           |
| Product analysis       | 0.048           | 0.048           |
| Sulfur, max:           |                 |                 |
| Heat analysis          | 0.050           | 0.050           |
| Product analysis       | 0.058           | 0.058           |
| Boron, min:            |                 |                 |
| Heat analysis          | 0.0005          | 0.0005          |
| Product analysis       | 0.0005          | 0.0005          |
### TABLE 2 Hardness Requirements

<table>
<thead>
<tr>
<th>Bolt or Stud Diameter, in.</th>
<th>Brinell Hardness Number</th>
<th>Rockwell C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4 to 1, incl</td>
<td>255 to 321</td>
<td>25 to 34</td>
</tr>
<tr>
<td>Over 1 to 1 1/2, incl</td>
<td>223 to 285</td>
<td>19 to 30</td>
</tr>
<tr>
<td>Over 1 1/2 to 2, incl</td>
<td>193 to 235</td>
<td>...</td>
</tr>
</tbody>
</table>

8.4.2 The gaging limit for bolts shall be verified during manufacture or use by assembly of a nut tapped as nearly as practical to the amount oversize shown above. In case of dispute, a calibrated thread ring gage of that same size (Class X tolerance, gage tolerance plus) is to be used. Assembly of the gage, or the nut described above, must be possible with hand effort following application of light machine oil to prevent galling and damage to the gage. These inspections, when performed to resolve disputes, are to be performed at the frequency and quality described in Table 6.

8.5 Electroplated Bolts and Studs—Unless otherwise specified, threads prior to plating shall conform to ANSI/A 563.

8.6 Unless otherwise specified, bolts to be used with nuts or tapped holes that have been tapped oversize, in accordance with Specification A 563, shall have Class 2A threads before hot-dip or mechanically deposited zinc coating. After zinc coating, the maximum limit of pitch and major diameter may exceed the Class 2A limit by the following amount:

<table>
<thead>
<tr>
<th>Diameter, in.</th>
<th>Oversize Limit, in. (mm) <strong>A</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4</td>
<td>0.016</td>
</tr>
<tr>
<td>5/32 , 3/16</td>
<td>0.017</td>
</tr>
<tr>
<td>7/32 , 1/8</td>
<td>0.018</td>
</tr>
<tr>
<td>9/32 to 1/4 , incl</td>
<td>0.020</td>
</tr>
<tr>
<td>5/32</td>
<td>0.022</td>
</tr>
<tr>
<td>1.0 to 1 1/4 , incl</td>
<td>0.024</td>
</tr>
<tr>
<td>1 1/8 , 1 1/2</td>
<td>0.027</td>
</tr>
<tr>
<td>1 1/4 to 3.0 , incl</td>
<td>0.050</td>
</tr>
</tbody>
</table>

**A** These values are the same as the overtapping required for zinc-coated nuts in Specification A 563.

8.6.1 Unless otherwise specified, bolts to be used with nuts or tapped holes that have been tapped oversize, in accordance with Specification A 563, shall have Class 2A threads before hot-dip or mechanically deposited zinc coating. After zinc coating, the maximum limit of pitch and major diameter may exceed the Class 2A limit by the following amount:

<table>
<thead>
<tr>
<th>Diameter, in.</th>
<th>Oversize Limit, in. (mm) <strong>A</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4</td>
<td>0.016</td>
</tr>
<tr>
<td>5/32 , 3/16</td>
<td>0.017</td>
</tr>
<tr>
<td>7/32 , 1/8</td>
<td>0.018</td>
</tr>
<tr>
<td>9/32 to 1/4 , incl</td>
<td>0.020</td>
</tr>
<tr>
<td>5/32</td>
<td>0.022</td>
</tr>
<tr>
<td>1.0 to 1 1/4 , incl</td>
<td>0.024</td>
</tr>
<tr>
<td>1 1/8 , 1 1/2</td>
<td>0.027</td>
</tr>
<tr>
<td>1 1/4 to 3.0 , incl</td>
<td>0.050</td>
</tr>
</tbody>
</table>

9. Workmanship, Finish, and Appearance

9.1 The bolts and studs shall be commercially smooth and free of burrs, laps, seams, cracks, and other injurious material or manufacturing defects which would make them unsuitable for the intended application.

9.2 Surface discontinuity limits shall be in accordance with Specification F 788/F 788M.

10. Number of Tests and Retests

10.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated. Individual heats of steel are not identified in the finished product.

10.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last completed set of mechanical tests for each stock size in each shipment.

10.3 When testing on a lot basis is specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all material of one type, that is, bolts or studs having the same nominal diameter and length offered for inspection at one time. From each lot, the number of tests for each specified property shall be as follows:

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and less</td>
<td>1</td>
</tr>
<tr>
<td>Over 800 to 8 000, incl</td>
<td>2</td>
</tr>
<tr>
<td>Over 8 000 to 22 000, incl</td>
<td>3</td>
</tr>
<tr>
<td>Over 22 000</td>
<td>5</td>
</tr>
</tbody>
</table>

10.4 Should any sample fail to meet the requirements of a specified test, double the original number of samples from the same lot shall be retested for the requirement(s) in which it failed. All the additional samples shall conform to the specification or the lot shall be rejected.

10.5 If any test specimen shows defective machining, it may be discarded and another specimen substituted.

11. Test Methods

11.1 Tests shall be conducted in accordance with Test Methods F 606.

11.2 The wedge test shall be applicable only to square and hexagon head bolts.

11.3 Studs shall be tested by the Axial Tension Method as described in the second paragraph of Axial Tension Testing of Full-Size Products, Test Methods section of Test Methods F 606.

12. Inspection

12.1 If the inspection described in 12.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

12.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him.

ASME B1.1 Class 2A and after plating shall not exceed the Class 3A maximum limits, that is, Class 2A plus the allowance.
that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser’s representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

13. Responsibility

13.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

14. Rejection and Rehearing

14.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

15. Product Marking

15.1 Manufacturers Identification—All bolt heads and one end of studs shall be marked with a unique identifier by the manufacturer to identify the manufacturer or private label distributor, as appropriate.

15.2 Type Identification—In addition to the requirements in 15.1, all bolt heads and one end of studs ¾ in. and larger, and whenever feasible studs less than ¾ in., shall be marked to identify the Type as follows:

15.3 Marking Method and Location—All markings shall be located on the top of the bolt head or stud end and may be either raised or depressed, at the option of the manufacturer.

15.4 Type and manufacturer’s or private label distributor’s identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.
16. Packaging and Package Marking

16.1 Packaging:

16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

16.1.2 When zinc-coated nuts are included on the same order as zinc coated bolts, the bolts and nuts shall be shipped in the same container.

16.1.3 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

16.2 Package Marking:

16.2.1 Each shipping unit shall include or be plainly marked with the following information:

### TABLE 4 Tensile Requirements for Fine-Thread Full-Size Bolts and Studs

<table>
<thead>
<tr>
<th>Bolt or Stud Diameter, in.</th>
<th>Threads per inch</th>
<th>Stress Area, (^{a}) in.(^2)</th>
<th>Tensile Load, min, lbf(^{b})</th>
<th>Proof Load, Length Measurement Method, lbf(^{a})</th>
<th>Alternative Proof Load, Yield Strength Method (0.2 % Offset), min, lbf(^{a})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1⁄4</td>
<td>28</td>
<td>0.0364</td>
<td>4 350</td>
<td>3 100</td>
<td>3 500</td>
</tr>
<tr>
<td>5⁄32</td>
<td>24</td>
<td>0.0580</td>
<td>6 950</td>
<td>4 950</td>
<td>5 350</td>
</tr>
<tr>
<td>3⁄16</td>
<td>24</td>
<td>0.0878</td>
<td>10 550</td>
<td>7 450</td>
<td>8 100</td>
</tr>
<tr>
<td>7⁄32</td>
<td>20</td>
<td>0.1187</td>
<td>14 500</td>
<td>10 100</td>
<td>10 900</td>
</tr>
<tr>
<td>1⁄4</td>
<td>20</td>
<td>0.1599</td>
<td>19 200</td>
<td>13 600</td>
<td>14 700</td>
</tr>
<tr>
<td>5⁄32</td>
<td>18</td>
<td>0.203</td>
<td>24 350</td>
<td>17 250</td>
<td>18 700</td>
</tr>
<tr>
<td>3⁄16</td>
<td>18</td>
<td>0.256</td>
<td>30 700</td>
<td>21 750</td>
<td>23 500</td>
</tr>
<tr>
<td>5⁄32</td>
<td>16</td>
<td>0.373</td>
<td>44 750</td>
<td>31 700</td>
<td>34 300</td>
</tr>
<tr>
<td>3⁄16</td>
<td>14</td>
<td>0.509</td>
<td>61 100</td>
<td>43 250</td>
<td>46 800</td>
</tr>
<tr>
<td>1⁄2</td>
<td>12</td>
<td>0.663</td>
<td>79 550</td>
<td>56 350</td>
<td>61 000</td>
</tr>
<tr>
<td>9⁄16</td>
<td>12</td>
<td>0.856</td>
<td>89 900</td>
<td>63 350</td>
<td>69 350</td>
</tr>
<tr>
<td>1⁄2</td>
<td>12</td>
<td>1.073</td>
<td>112 650</td>
<td>79 400</td>
<td>86 900</td>
</tr>
<tr>
<td>13⁄16</td>
<td>12</td>
<td>1.315</td>
<td>138 100</td>
<td>97 300</td>
<td>106 500</td>
</tr>
<tr>
<td>1⁄2</td>
<td>12</td>
<td>1.581</td>
<td>166 000</td>
<td>117 000</td>
<td>128 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^{a}\) See footnote \(B\) in Table 3.
\(^{b}\) See footnote \(C\) in Table 3.

### TABLE 5 Tensile Requirements for Specimens Machined from Bolts and Studs

<table>
<thead>
<tr>
<th>Bolt or Stud Diameter, in.</th>
<th>Tensile Strength, min, psi (MPa)</th>
<th>Yield Strength, min, psi (MPa)</th>
<th>Elongation in 4D, min, %</th>
<th>Reduction of Area, min, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1⁄4 to 1, incl</td>
<td>120 000 (825)</td>
<td>92 000 (635)</td>
<td>14</td>
<td>35</td>
</tr>
<tr>
<td>Over 1 to 1 1⁄2, incl</td>
<td>105 000 (725)</td>
<td>81 000 (560)</td>
<td>14</td>
<td>35</td>
</tr>
<tr>
<td>Over 1 1⁄2 to 3, incl</td>
<td>95 000 (620)</td>
<td>58 000 (400)</td>
<td>14</td>
<td>35</td>
</tr>
</tbody>
</table>

### TABLE 6 Sample Sizes and Acceptance Numbers for Inspection of Hot-Dip or Mechanically Deposited Zinc-Coated Threads

<table>
<thead>
<tr>
<th>Lot Size</th>
<th>Sample Size(^{a,b})</th>
<th>Acceptance Number(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>91</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>151</td>
<td>32</td>
<td>3</td>
</tr>
<tr>
<td>281</td>
<td>50</td>
<td>5</td>
</tr>
<tr>
<td>501</td>
<td>80</td>
<td>7</td>
</tr>
<tr>
<td>1 201</td>
<td>125</td>
<td>10</td>
</tr>
<tr>
<td>3 201</td>
<td>200</td>
<td>14</td>
</tr>
<tr>
<td>10 001</td>
<td>315</td>
<td>21</td>
</tr>
</tbody>
</table>

\(^{a}\) Sample sizes of acceptance numbers are extracted from “Single Sampling Plan for Normal Inspection,” Table IIA, MIL-STD-105.

\(^{b}\) Inspect all bolts in the lot if the lot size is less than the sample size.

16.2.1.1 ASTM designation and type,

16.2.1.2 Size,

16.2.1.3 Name and brand or trademark of the manufacturer,

16.2.1.4 Number of pieces,

16.2.1.5 Purchase order number, and

16.2.1.6 Country of origin.

17. Keywords

17.1 bolts; carbon steel; steel; studs
SUPPLEMENTARY REQUIREMENTS

S1. Marking

S1.1 Studs that are continuously threaded with the same class of thread shall be marked on each end with the marking required by Section 15.

S1.2 Marking small sizes (customarily less than 0.375 in. (9.525 mm)) may not be practical. Consult the producer for the minimum size that can be marked.

SUMMARY OF CHANGES

Committee F16 has identified the location of selected changes to this standard since the last issue, A 449–00, that may impact the use of this standard. (Approved Jan. 1, 2004.)

(I) Added Section 1.7 that references Terminology F 1789.
Standard Specification for Carbon Steel Lifting Eyes

This standard is issued under the fixed designation A 489; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers weldless forged, quenched, and tempered carbon steel threaded lifting eyes (formerly eyebolts) for overhead lifting.

NOTE 1—Lifting eyes carrying this specification number even though they are liquid quenched and tempered may be processed from carbon steel which, in the composition range permitted by this specification, could have a fracture appearance transition temperature (50 % shear) higher than operating temperatures. Therefore, in order to minimize the possibility of a brittle cleavage failure, these lifting eyes should never be loaded above the proof load, and should not be used when surface discontinuities exist on the lifting eyes.

1.2 The specification includes two types denoting shank pattern and one style denoting shank length (both defined in ANSI/ASME B 18.15) as follows:

1.2.1 Type 1—Plain pattern (straight shank).
1.2.2 Type 2—Shoulder pattern.
1.2.3 Style B—Short length.

1.3 The values stated in inch-pound units are to be regarded as the standard. The SI values given in parentheses are for information only.

1.4 Terms used in this specification are defined in Specification F 1789 unless otherwise defined herein.

2. Referenced Documents

2.1 ASTM Standards:
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
D 3951 Practice for Commercial Packaging
E 112 Test Methods for Determining Average Grain Size
F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

2.2 ANSI/ASME Standards:
B 1.1 Unified Inch Screw Threads
B 18.15 Forged Lifting Eyes
B 18.24.1 Part Identifying Number (PIN) Code System

3. Ordering Information

3.1 Orders for lifting eyes under this specification should include the following information:
3.1.1 ASTM specification number and date of issue.
3.1.2 Name of product, that is lifting eyes.
3.1.3 Type and style (See 1.2, Type 1 Style B) will be furnished when a Type and Style is not specified.
3.1.4 Drawing, if nonstandard lifting eyes are required (See 8.3).
3.1.5 Number of pieces.
3.1.6 Size, nominal thread diameter and threads.
3.1.7 Certification, if required (See Section 14).
3.1.8 Supplementary requirements, if required.
3.1.9 Other special requirements.
3.1.10 For establishment of a part identifying system, see ASME B18.24.1.

4. Materials and Manufacture

4.1 Melting Process—The steel shall be made by the open-hearth, basic-oxygen, or electric-furnace process and shall be made to a fine-grain practice.
4.2 Forging—Lifting eyes shall be forged without welds.
4.3 Heat Treatment—The lifting eyes shall be liquid quenched and tempered prior to machining the threaded end.
4.4 Machining—The lifting eyes shall be machined after the quench and temper operation.
4.5 Threads—The lifting eyes shall be threaded. Threads may be rolled, cut, or ground.

* A Summary of Changes section appears at the end of this standard.
5. Chemical Composition

5.1 Limits—The lifting eyes shall be manufactured from steels having a heat analysis conforming to the requirements in Table 1.

5.2 Product Analysis:

5.2.1 Analyses of finished lifting eyes may be made by the purchaser or may be requested to be made by the manufacturer. The composition thus determined shall conform to the product analysis requirements specified in Table 1.

5.3 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 Proof Load—The lifting eyes shall withstand the proof load specified in Table 2.

6.1.1 The proof load shall be defined as the load that can be applied without causing permanent deformation exceeding 0.01 in. (0.255 mm) between prick punch marks at opposite ends of the diameter across the eye. The proof load shall be applied through a mandrel having a diameter of one half the nominal inside diameter of the eye.

6.2 Breaking Strength—The lifting eyes shall conform to the breaking strength specified in Table 2.

6.2.1 The breaking strength shall be determined by screwing the lifting eye to the full thread engagement into a block secured in one jaw of the testing machine and held to the other jaw by means of a mandrel passing through the eye. Failure of the lifting eye below the specified breaking strength constitutes a failure.

6.3 Tensile Test Requirements—A specimen machined from a finished lifting eye shall conform to the tensile requirements specified in Table 3.

6.3.1 When the lifting eye is too small to have a tensile bar machined from it, a test specimen from the same heat of steel and same heat treatment lot or charge as the lifting eyes to be tested shall be used to establish the tensile properties of the material in accordance with 6.3.

6.3.2 The tensile properties shall be determined in accordance with Test Methods F 606.

6.4 Bend Test—Type 1 straight shank lifting eyes 1½ in. (36.1 mm) or less in diameter, after being screwed into a steel block to the full thread length and bent 45° by pressure, shall not exhibit any visible surface ruptures in the unthreaded section of the lifting eye when examined at 10× magnification.

6.5 Impact Strength—The lifting eyes shall have an average Charpy V-notch impact strength of not less than 35 ft·lbf (47 J) at 0°C (32°F).

6.5.1 The impact strength shall be the average of three specimens tested. Not more than one specimen shall exhibit a value below the specified minimum average, and in no case shall a value be less than 23 ft·lbf (31 J).

6.5.2 Whenever possible, test specimens shall be taken from the shank and shall conform to the standard 10 by 10-mm Charpy V-notch specimen shown in Test Methods and Definitions A 370. When lifting eyes are too small for standard-size specimens, subsizes may be used, or specimens that represent the same heat and have been subjected to the same forging and heat-treating practices as the lifting eyes they represent may be taken from separate test coupons.

6.5.3 The impact properties shall be determined in accordance with Test Methods and Definitions A 370.

7. Grain Size

7.1 The finished lifting eyes shall have an as-finished grain size of ASTM No. 5 or finer.

7.2 The grain size shall be rated from a broken tensile specimen end representing a heat treated lot of one size.
7. Tests shall be conducted in accordance with Test Methods E 112.

8. Dimensions
8.1 The dimensions of the lifting eyes shall conform to the requirements specified in latest issue of ANSI/ASME B 18.15 unless otherwise specified.
8.2 The Type and Style shall be as specified by the purchaser. When not specified, Type 1, Style B shall be furnished.
8.3 When dimensions other than specified in 8.1 are required, they shall be in accordance with the purchaser’s drawing. In such cases, the proof load and breaking strength requirements are not applicable because the manufacturer cannot be assured that the purchaser’s proprietary design can withstand the loads in this specification. The machined specimen tensile, impact, and bend tests shall apply in addition to all other requirements of this specification.

9. Threads
9.1 The lifting eyes shall be threaded. Threads shall conform to the Unified Coarse Thread Series as specified in ANSI/ASME B 1.1 and shall have Class 2A tolerances.

10. Workmanship, Finish, and Appearance
10.1 The lifting eyes shall be descaled.
10.2 The lifting eyes shall be free of injurious imperfections that would make them unsuitable for the intended use. The threads shall be undamaged upon receipt by the purchaser as demonstrated by the ability to accept a Go Ring Gage with normal hand force.

11. Number of Tests and Retests
11.1 Lot Definition:
11.1.1 A lot shall consist of forgings produced from one heat of steel per treatment charge.
11.1.2 If more than one heat of steel is used per treatment charge, all heats must be tested as defined in 11.2.1.
11.1.3 A treatment charge is defined as one furnace load of lifting eyes of the same size per quench and temper operation or in a continuous furnace as every 8 h of continuous operation in quenching and tempering of lifting eyes of the same size.
11.2 Number of Tests:
11.2.1 Each lot shall be tested for proof load, breaking strength, tensile, and bend properties at the frequency specified below:

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and under</td>
<td>1</td>
</tr>
<tr>
<td>801 to 8000</td>
<td>2</td>
</tr>
<tr>
<td>8001 to 22,000</td>
<td>3</td>
</tr>
<tr>
<td>Over 22,000</td>
<td>5</td>
</tr>
</tbody>
</table>

11.2.2 The number of tests for impact strength and grain size shall be in accordance with the manufacturer’s standard quality control practices. A specific number of tests are not required but the lifting eyes shall be produced by manufacturing practices and subject to mill tests and inspection to ensure compliance with the specified requirements.
11.3 Retests:
11.3.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer may retest the same lot if double the number of samples required for that lot are retested, in which case all additional tests shall meet the requirements of the specification.
11.3.2 If any test specimen shows defective machining, it may be discarded and another specimen substituted.

12. Inspection
12.1 The manufacturer shall afford the purchaser’s quality assurance representative all reasonable facilities necessary to satisfy him that the lifting eyes are being produced and furnished in accordance with this specification. Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer’s operations. All tests and inspections shall be made at the place of manufacture, unless otherwise agreed to.
12.2 Lots represented by lifting eyes tested by the purchaser that fail to meet the specified requirements shall be subject to rejection.

13. Rejection and Rehearing
13.1 Lifting eye lots that fail to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

14. Certification
14.1 When specified by the purchaser, a test report shall be furnished for each lot showing the following:
14.1.1 Heat analysis and heat number(s),
14.1.2 Results of proof load, breaking strength, tensile, and bend tests,
14.1.3 Results of any supplementary requirements invoked,
14.1.4 Statement of compliance with grain size and impact requirements,
14.1.5 Purchase order number,
14.1.6 Lot number(s), and
14.1.7 ASTM specification number, including type, style, and date of issue.

15. Responsibility
15.1 The party responsible for the lifting eye shall be the organization that supplies the lifting eye to the purchaser and certifies that the lifting eye was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

16. Product Marking
16.1 Each lifting eye shall have the manufacturer’s name or identification mark forged in raised characters on the surface of the lifting eye.

17. Packaging and Package Marking
17.1 Packaging:
17.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.
17.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.
17.2 Package Marking:
17.2.1 Each shipping unit shall include or be plainly marked with the following information:
17.2.1.1 ASTM designation and type,
17.2.1.2 Size,
17.2.1.3 Name and brand or trademark of the manufacturer,
17.2.1.4 Number of pieces,
17.2.1.5 Purchase order number, and
17.2.1.6 Country of origin.

18. Keywords
18.1 carbon steel; eyebolts; lifting eye; steel

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser as part of the purchaser’s order or contract and for all agencies of the United States Government.

S1. Impact Tests

S1.1 Impact tests shall be conducted on each lot. The number of tests shall be in accordance with 11.2.1. The results shall be reported to the purchaser.

S2. Proof Load Tests—Proof load tests shall be conducted on each lifting eye. The results shall be reported to the purchaser.

S3. Grain Size Tests—Grain size shall be determined on each tensile specimen. The results shall be reported to the purchaser.

SUMMARY OF CHANGES

This section identifies the location of selected changes to this standard that have been incorporated since the A 489–00 issue. For the convenience of the user, Committee F16 has highlighted those changes that impact the use of this standard. This section may also include descriptions of the changes or reasons for the changes, or both.

(Apraised Oct. 1, 2003.)

(1) Added Section 1.4 that references Specification F 1789 for definitions of terms.
Standard Specification for
Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength

This standard is issued under the fixed designation A 490; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers two types of quenched and tempered, alloy steel, heavy hex structural bolts having a tensile strength of 150 to 173 ksi.

1.2 These bolts are intended for use in structural connections. These connections are covered under the requirements of the Specification for Structural Joints Using Specification A 325 or A 490 bolts, approved by the Research Council on Structural Connections; endorsed by the American Institute of Steel Construction and by the Industrial Fastener Institute.2

1.3 The bolts are furnished in sizes 1⁄2 to 1½ in., inclusive. They are designated by type denoting chemical composition as follows:

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>Medium carbon alloy steel</td>
</tr>
<tr>
<td>Type 2</td>
<td>Withdrawn in 2002</td>
</tr>
<tr>
<td>Type 3</td>
<td>Weathering steel</td>
</tr>
</tbody>
</table>

1.4 This specification provides that heavy hex structural bolts shall be furnished unless other dimensional requirements are specified on the purchase order.

1.5 Terms used in this specification are defined in Specification F 1789 unless otherwise defined herein.

1.6 For metric bolts, see Specification A 490M Classes 10.9 and 10.9.3

1.7 The following safety hazards caveat pertains only to the Test Methods portion, Section 1412 of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards: 3

- A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service
- A 325 Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
- A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
- A 563 Specification for Carbon and Alloy Steel Nuts
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- D 3951 Practice for Commercial Packaging
- E 384 Test Method for Microindentation hardness of Materials
- E 709 Guide for Magnetic Particle Examination
- E 1444 Practice for Magnetic Particle Inspection
- F 436 Specification for Hardened Steel Washers
- F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
- F 788/F 788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series
- F 959 Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners
- F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
- F 1789 Terminology for F16 Mechanical Fasteners

2.2 ASME Standards: 4

- B1.1 Unified Screw Threads

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* This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.02 on Steel Bolts, Nuts, Rivets, and Washers.


2 Available from American Institute of Steel Construction (AISC), One E. Wacker Dr., Suite 3100, Chicago, IL 60601-2001.

3 For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard’s Document Summary page on the ASTM website.

4 Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

*A Summary of Changes section appears at the end of this standard.
and have a surface finish for each type of bolt as follows:

A 490 heavy hex structural bolts. The nuts shall be of the class
A 563 are the recommended nuts for use with Specification
shall have a surface finish for each type of bolt as follows:

ASTM F 436 are the recommended washers for use with

3. Ordering Information

3.1 Orders for heavy hex structural bolts under this speci-
fication shall include the following:

3.1.1 Quantity (number of pieces of bolts and accessories);
3.1.2 Size, including nominal bolt diameter, thread pitch,
and bolt length. The thread length shall not be changed;
3.1.3 Name of product: heavy hex structural bolts, or other
such bolts as specified;
3.1.4 Type of bolt (Type 1 or 3). When type is not specified,
either Type 1 or Type 3 shall be furnished at the supplier’s
option;
3.1.5 ASTM designation and year of issue,
3.1.6 Other components such as nuts, washers, and washer-
type direct tension indicators, if required;
3.1.7 Test Reports, if required (see 15); and
3.1.8 Special requirements.
3.1.9 For establishment of a part identifying system, see
ASME B18.24.1.

NOTE 1—A typical ordering description follows: 1000 pieces 1–8 in.
dia × 4 in. long heavy hex structural bolt, Type 1, ASTM A 490 – 02; each
with two hardwashed, ASTM F 436 Type 1; and one heavy hex nut,
ASTM A 563 Grade DH.

3.2 Recommended Nuts:

3.2.1 Nuts conforming to the requirements of Specification
A 563 are the recommended nuts for use with Specification
A 490 heavy hex structural bolts. The nuts shall be of the class
and have a surface finish for each type of bolt as follows:

<table>
<thead>
<tr>
<th>Bolt Type and Finish</th>
<th>Nut Class and Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, plain (uncoated)</td>
<td>A 563—DH, DH3 plain (uncoated)</td>
</tr>
<tr>
<td>3, weathering steel</td>
<td>A 563—DH3, weathering steel</td>
</tr>
</tbody>
</table>

3.2.2 Alternatively, nuts conforming to Specification A 194
Gr. 2H plain (uncoated) are considered a suitable substitute for
use with Specification A 490 Type 1 heavy hex structural bolts.

3.3 Recommended Washers—Washers conforming to Speci-
fication F 436 are the recommended washers for use with
Specification A 490 heavy hex structural bolts. The washers
shall have a surface finish for each type of bolt as follows:

<table>
<thead>
<tr>
<th>Bolt Type and Finish</th>
<th>Washer Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, plain (uncoated)</td>
<td>plain (uncoated)</td>
</tr>
<tr>
<td>3, weathering steel</td>
<td>weathering steel</td>
</tr>
</tbody>
</table>

3.4 Other Accessories—When compressible washer type
direct tension indicators are specified to be used with these
bolts, they shall conform to Specification F 959 Type 490.

4. Materials and Manufacture

4.1 Heat Treatment—Type 1 and Type 3 bolts shall be heat
treated by quenching in oil from the austenitic temperature and
then tempered by reheating to a temperature of not less than
800°F.

4.2 Threading:
The threads shall be cut or rolled.

4.3 Protective Coatings—The bolts shall not be coated by
hot-dip zinc coating, mechanical deposition, or electroplating
with zinc or other metallic coatings (Note 2).

NOTE 2—For more detail see the H. E. Townsend Report “Effects of
Zinc Coatings on Stress Corrosion Cracking and Hydrogen Embrittlement
of Low Alloy Steel,” published in Metallurgical Transactions, Vol. 6, April
1975.

5. Chemical Composition

5.1 Type 1 bolts shall be alloy steel conforming to the
chemical composition specified in Table 1. The steel shall
contain sufficient alloying elements to qualify it as an alloy
steel (see Note 3).

NOTE 3—Steel is considered to be alloy by the American Iron and Steel
Institute when the maximum of the range given for the content of alloying
elements exceeds one or more of the following limits: manganese, 1.65 %;
silicon, 0.60 %; copper, 0.60 %; or in which a definite range or a definite
minimum quantity of any of the following elements is specified or
required within the limits of the recognized field of constructional alloy
steels: aluminum, chromium up to 3.99 %, cobalt, columbium, molybde-
num, nickel, titanium, tungsten, vanadium, zirconium, or any other
alloying elements added to obtain a desired alloying effect.

5.2 Type 3 bolts shall be weathering steel conforming to the
chemical composition requirements in Table 2. See Guide
G 101 for methods of estimating the atmospheric corrosion
resistance of low alloy steel.

5.3 Product analyses made on finished bolts representing
each lot shall conform to the product analysis requirements
specified in Table 1 or Table 2, as applicable.

5.4 Heats of steel to which bismuth, selenium, tellurium, or
lead has been intentionally added shall not be used for bolts
furnished to this specification. Compliance with this require-
ment shall be based on certification that steels having these
elements intentionally added were not used.

5.5 Chemical analyses shall be performed in accordance
with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 Hardness—The bolts shall conform to the hardness
specified in Table 3.

6.2 Tensile Properties:

<table>
<thead>
<tr>
<th>Element</th>
<th>Heat Analysis, %</th>
<th>Product Analysis, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For sizes through 1½ in.</td>
<td>0.30–0.48</td>
<td>0.28–0.50</td>
</tr>
<tr>
<td>For size 1½ in.</td>
<td>0.35–0.53</td>
<td>0.33–0.55</td>
</tr>
<tr>
<td>Phosphorus, max</td>
<td>0.040</td>
<td>0.045</td>
</tr>
<tr>
<td>Sulfur, max</td>
<td>0.040</td>
<td>0.045</td>
</tr>
<tr>
<td>Alloying Elements</td>
<td>→ See 5.1 ←</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 2 Chemical Requirements for Type 3 Bolts

<table>
<thead>
<tr>
<th>Element</th>
<th>Heat Analysis, %</th>
<th>Product Analysis, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sizes 0.75 in. and smaller</td>
<td>0.20–0.53</td>
<td>0.19–0.55</td>
</tr>
<tr>
<td>Sizes larger than 0.75 in.</td>
<td>0.30–0.53</td>
<td>0.28–0.55</td>
</tr>
<tr>
<td>Manganese, min</td>
<td>0.40</td>
<td>0.37</td>
</tr>
<tr>
<td>Phosphorus, max</td>
<td>0.035</td>
<td>0.040</td>
</tr>
<tr>
<td>Sulfur, max</td>
<td>0.040</td>
<td>0.045</td>
</tr>
<tr>
<td>Copper</td>
<td>0.20–0.60</td>
<td>0.17–0.63</td>
</tr>
<tr>
<td>Chromium, min</td>
<td>0.45</td>
<td>0.42</td>
</tr>
<tr>
<td>Nickel, min</td>
<td>0.20</td>
<td>0.17</td>
</tr>
<tr>
<td>or Molybdenum, min</td>
<td>0.15</td>
<td>0.14</td>
</tr>
</tbody>
</table>

6.2.1 Except as permitted in 6.2.2 for long bolts and 6.2.3 for short bolts, sizes 1.00 in. and smaller having a length of 2¼ D and longer and sizes larger than 1.00 in. having a length of 3D and longer shall be wedge tested full size and shall conform to the minimum and maximum wedge tensile load, and proof load or alternative proof load specified in Table 4. The load achieved during proof load testing shall be equal to or greater than the specified proof load.

6.2.2 When the length of the bolt makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements specified in Table 5. When bolts are tested by both full-size and machined specimen methods, the full-size test shall take precedence.

6.2.3 Sizes 1.00 in. and smaller having a length shorter than 2¼ D down to 2D, inclusive, that cannot be wedge tensile tested shall be axially tension tested full size and shall conform to the minimum tensile load and proof load or alternate proof load specified in Table 4. Sizes 1.00 in. and smaller having a length shorter than 2D that cannot be axially tensile tested shall be qualified on the basis of hardness.

6.2.4 For bolts on which hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event of low hardness readings.

7. Carburization/Decarburization

7.1 Definition—This test is intended to evaluate the presence or absence of carburization and decarburization as determined by the difference in microhardness near the surface and core.

7.2 Requirements:

7.2.1 Carburization—The bolts shall show no evidence of a carburized surface when evaluated in accordance with the hardness methods established in SAE J121.

7.2.2 Decarburization—Hardness value differences shall not exceed the requirements set forth for decarburization in SAE J121 for Class 2/3H materials.

7.3 Procedure—Testing for carburization/decarburization shall be performed in accordance with the microhardness (referee) methods established in SAE J121.

8. Dimensions

8.1 Head and Body:

8.1.1 Unless otherwise specified, bolts shall conform to the dimensions for heavy hex structural bolts specified in ASME B18.2.6.

8.1.2 The thread length shall not be changed from that specified in ASME B18.2.6 for heavy hex structural bolts. Bolts requiring thread lengths other than those required by this specification shall be ordered under Specification A 354 Gr. BD.

8.2 Threads—Threads shall be the Unified Coarse Thread Series as specified in ASME B1.1 and shall have Class 2A tolerances. When specified, 8 pitch thread series shall be used on bolts over 1 in. in diameter.

9. Workmanship

9.1 The allowable limits, inspection, and evaluation of the surface discontinuities, quench cracks, forging cracks, head bursts, shear bursts, seams, folds, thread laps, voids, tool marks, nicks, and gouges shall be in accordance with Specification F 788/F 788M (see Note 4).

NOTE 4—Specifications F 788/F 788M and F 1470 do not guarantee 100 % freedom from head bursts. Sampling is designed to provide a 95 % confidence level of freedom from head bursts in any test lot. Head bursts, within the limits in Specification F 788/F 788M, are unsightly but do not affect mechanical properties or functional requirements of the bolt.

10. Magnetic Particle Inspection for Longitudinal Discontinuities and Transverse Cracks

10.1 Requirements:

10.1.1 Each sample representative of the lot shall be magnetic particle inspected for longitudinal discontinuities and transverse cracks.

10.1.2 The lot, as represented by the sample, shall be free from nonconforming bolts, as defined in 10.3, when inspected in accordance with 10.2.1-10.2.4.

10.2 Inspection Procedure:

10.2.1 The inspection sample shall be selected at random from each lot in accordance with Table 6 and examined for longitudinal discontinuities and transverse cracks.

10.2.2 Magnetic particle inspection shall be conducted in accordance with Practice E 709 or E 1444. Practice E 709 shall be used for referee purposes. If any nonconforming bolt is found during the manufacturer’s examination of the lot selected in 10.2.1, the lot shall be 100 % magnetic particle inspected, and all nonconforming bolts shall be removed and scrapped or destroyed.

10.2.3 Eddy current or liquid penetrant inspection shall be an acceptable substitute for the 100 % magnetic particle inspection when nonconforming bolts are found and 100 % inspection is required. On completion of the eddy current or liquid penetrant inspection, a random sample selected from each lot in accordance with Table 5 shall be re-examined by the magnetic particle method. In case of controversy, the magnetic particle test shall take precedence.

10.2.4 Magnetic particle indications of themselves shall not be cause for rejection. If in the opinion of the quality assurance representative the indications may be cause for rejection, a sample taken in accordance with Table 5 shall be examined by microscopic examination or removal by surface grinding to determine if the indicated discontinuities are within the specified limits.

10.3 Definitions:
10.3.1 Nonconforming Bolts—Any bolt with a longitudinal discontinuity (located parallel to the axis of the bolt in the threads, body, fillet, or underside of head), with a depth normal to the surface greater than 0.03D, where D is the nominal diameter in inches, shall be considered nonconforming. In addition, any bolt with a transverse crack (located perpendicular to the axis of the bolt in the threads, body, fillet, or underside of head) detectable by magnetic particle inspection, shall be considered nonconforming.

### TABLE 3 Hardness Requirements for Bolts

<table>
<thead>
<tr>
<th>Size, in.</th>
<th>Length, in.</th>
<th>Brinell min</th>
<th>Brinell max</th>
<th>Rockwell C min</th>
<th>Rockwell C max</th>
</tr>
</thead>
<tbody>
<tr>
<td>½ to 1, incl.</td>
<td>Less than 2D&lt;sup&gt;A&lt;/sup&gt;</td>
<td>311</td>
<td>352</td>
<td>33</td>
<td>39</td>
</tr>
<tr>
<td>2D&lt;sup&gt;A&lt;/sup&gt; and longer</td>
<td>...</td>
<td>352</td>
<td>...</td>
<td>33</td>
<td>39</td>
</tr>
<tr>
<td>Over 1 to 1½, incl.</td>
<td>Less than 3D&lt;sup&gt;A&lt;/sup&gt;</td>
<td>311</td>
<td>352</td>
<td>33</td>
<td>39</td>
</tr>
<tr>
<td>3D&lt;sup&gt;A&lt;/sup&gt; and longer</td>
<td>...</td>
<td>352</td>
<td>...</td>
<td>33</td>
<td>39</td>
</tr>
</tbody>
</table>

<sup>A</sup> Heavy hex structural bolts 1 in. and smaller and shorter than 2D are subject only to minimum and maximum hardness. Heavy hex structural bolts larger than 1 through 1½, incl., in diameter and shorter than 3D are subject only to minimum and maximum hardness.

### TABLE 4 Tensile Load Requirements for Full-Size Bolts

<table>
<thead>
<tr>
<th>Bolt Size, Threads per Inch, and Series Designation</th>
<th>Stress Area,&lt;sup&gt;A&lt;/sup&gt; in.²</th>
<th>Tensile Load,&lt;sup&gt;B&lt;/sup&gt; lbf</th>
<th>Proof Load,&lt;sup&gt;B&lt;/sup&gt; lbf</th>
<th>Alternative Proof Load,&lt;sup&gt;B&lt;/sup&gt; lbf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column 1</td>
<td>Column 2</td>
<td>Column 3</td>
<td>Column 4</td>
<td>Column 5</td>
</tr>
<tr>
<td>½-13 UNC</td>
<td>0.142</td>
<td>21 300</td>
<td>24 600</td>
<td>17 050</td>
</tr>
<tr>
<td>¾-11 UNC</td>
<td>0.226</td>
<td>33 900</td>
<td>39 100</td>
<td>27 100</td>
</tr>
<tr>
<td>¾-10 UNC</td>
<td>0.334</td>
<td>50 100</td>
<td>57 800</td>
<td>40 100</td>
</tr>
<tr>
<td>¾-9 UNC</td>
<td>0.462</td>
<td>69 300</td>
<td>79 950</td>
<td>55 450</td>
</tr>
<tr>
<td>1-8 UNC</td>
<td>0.606</td>
<td>90 900</td>
<td>104 850</td>
<td>72 700</td>
</tr>
<tr>
<td>1¼-7 UNC</td>
<td>0.763</td>
<td>114 450</td>
<td>132 000</td>
<td>91 550</td>
</tr>
<tr>
<td>1¼-8 UN</td>
<td>0.790</td>
<td>118 500</td>
<td>136 700</td>
<td>94 800</td>
</tr>
<tr>
<td>1¼-7 UN</td>
<td>0.969</td>
<td>145 350</td>
<td>167 650</td>
<td>116 300</td>
</tr>
<tr>
<td>1¼-8 UN</td>
<td>1.000</td>
<td>150 000</td>
<td>173 000</td>
<td>120 000</td>
</tr>
<tr>
<td>1½-6 UNC</td>
<td>1.155</td>
<td>173 250</td>
<td>199 850</td>
<td>138 600</td>
</tr>
<tr>
<td>1½-8 UN</td>
<td>1.233</td>
<td>185 000</td>
<td>213 350</td>
<td>148 000</td>
</tr>
<tr>
<td>1½-6 UN</td>
<td>1.405</td>
<td>210 750</td>
<td>243 100</td>
<td>168 800</td>
</tr>
<tr>
<td>1½-8 UN</td>
<td>1.492</td>
<td>223 800</td>
<td>258 150</td>
<td>179 000</td>
</tr>
</tbody>
</table>

<sup>A</sup> The stress area is calculated as follows:

\[
A_s = 0.7854 \left[D - \left(0.9743 / n\right)\right]^2
\]

where:

- \(A_s\) = stress area, in.²
- D = nominal bolt size, and
- n = threads per inch.

<sup>B</sup> Loads tabulated and loads to be used for tests of full-size bolts larger than 1½ in. in diameter are based on the following:

<table>
<thead>
<tr>
<th>Bolt Size</th>
<th>Column 3</th>
<th>Column 4</th>
<th>Column 5</th>
<th>Column 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>½ to 1½ in., incl</td>
<td>150 000 psi</td>
<td>173 000 psi</td>
<td>120 000 psi</td>
<td>130 000 psi</td>
</tr>
</tbody>
</table>

### TABLE 5 Tensile Strength Requirements for Specimens Machined from Bolts

<table>
<thead>
<tr>
<th>Bolt Size, in.</th>
<th>Tensile Strength, psi</th>
<th>YS Strength (0.2 % offset), min, psi</th>
<th>YS Strength (0.2 % offset), max, psi</th>
<th>Elongation in 2 in. or 50 mm, min, %</th>
<th>Reduction of Area, min, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>½ to 1½ in., incl</td>
<td>150 000</td>
<td>173 000</td>
<td>130 000</td>
<td>14</td>
<td>40</td>
</tr>
</tbody>
</table>

### TABLE 6 Sample Sizes with Acceptance and Rejection Numbers for Inspection of Rejectable Longitudinal Discontinuities and Transverse Cracks

<table>
<thead>
<tr>
<th>Lot Size</th>
<th>Sample Size&lt;sup&gt;A&lt;/sup&gt;</th>
<th>Acceptance Number&lt;sup&gt;B&lt;/sup&gt;</th>
<th>Rejection Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 50</td>
<td>all</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>51 to 500</td>
<td>50</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>501 to 1200</td>
<td>80</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1201 to 3200</td>
<td>125</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>3201 to 10 000</td>
<td>200</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

<sup>A</sup> Inspect all bolts in the lot if lot size is less than sample size.
11. Number of Tests and Retests

11.1 Testing Responsibility:

11.1.1 Each lot shall be tested by the manufacturer prior to shipment in accordance with the lot identification control quality assurance plan in 11.2-11.5.

11.1.2 When bolts are furnished by a source other than the manufacturer, the Responsible Party as defined in 16.1 shall be responsible for assuring all tests have been performed and the bolts comply with the requirements of this specification.

11.2 Purpose of Lot Inspection—The purpose of a lot inspection program shall be to ensure that each lot as represented by the samples tested conforms to the requirements of this specification. For such a plan to be fully effective, it is essential that secondary processors, distributors, and purchasers maintain the identification and integrity of each lot until the product is installed.

11.3 Lot Method—All bolts shall be processed in accordance with a lot identification-control quality assurance plan. The manufacturer, secondary processors, and distributors shall identify and maintain the integrity of each lot of bolts from raw-material selection through all processing operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

11.4 Lot Definition—A lot shall be a quantity of uniquely identified heavy hex structural bolts of the same nominal size and length produced consecutively at the initial operation from a single mill heat of material and processed at one time, by the same process, in the same manner, so that statistical sampling is valid. The identity of the lot and lot integrity shall be maintained throughout all subsequent operations and packaging.

11.5 Number of Tests:

11.5.1 The minimum number of tests from each lot for the tests specified below shall be as follows:

<table>
<thead>
<tr>
<th>Tests</th>
<th>Number of Tests in Accordance with</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness, tensile strength, proof load</td>
<td>Guide F 1470a</td>
</tr>
<tr>
<td>Surface discontinuities</td>
<td>Specification F 788/F 788M</td>
</tr>
<tr>
<td>Magnetic particle inspection</td>
<td>Table 5</td>
</tr>
<tr>
<td>Dimensions and thread fit</td>
<td>ASME B18.2.6</td>
</tr>
</tbody>
</table>

11.5.2 For carburization and decarburization tests, not less than one sample unit per manufactured lot shall be tested for microhardness.

12. Test Methods

12.1 Tensile, Proof Load, and Hardness:

12.1.1 Tensile, proof load, and hardness tests shall be conducted in accordance with Test Methods F 606.

12.1.2 Tensile strength shall be determined using the Wedge or Axial Tension Testing Method of Full Size Product Method or the Machined Test Specimens Method, depending on size and length as specified in 6.2.1-6.2.4. Fracture on full-size tests shall be in the body or threads of the bolt without a fracture at the junction of the head and body.

12.1.3 Proof load shall be determined using Method 1, Length Measurement, or Method 2, Yield Strength, at the option of the manufacturer.

12.2 Carburization/Decarburization—Tests shall be conducted in accordance with SAE J121 Hardness Method.

12.3 Microhardness—Tests shall be conducted in accordance with Test Method E 384.

12.4 Magnetic Particle—Inspection shall be conducted in accordance with Section 10.

13. Inspection

13.1 If the inspection described in 13.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

13.2 The purchaser’s representative shall have free entry to all parts of manufacturer’s works or supplier’s place of business that concern the manufacture of the material ordered. The manufacturer or supplier shall afford the purchaser’s representative all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser’s representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the manufacturer’s works or supplier’s place of business.

14. Rejection and Rehearing

14.1 Disposition of nonconforming material shall be in accordance with Guide F 1470 section titled “Disposition of Nonconforming Lots.”

15. Certification

15.1 When specified on the purchase order, the manufacturer or supplier, whichever is the responsible party as defined in Section 16 shall furnish the purchaser a test report that includes the following:

15.1.1 Heat analysis, heat number, and a statement certifying that heats having bismuth, selenium, tellurium, or lead intentionally added were not used to produce the bolts;

15.1.2 Results of hardness, tensile, and proof load tests;

15.1.3 Results of magnetic particle inspection for longitudinal discontinuities and transverse cracks;

15.1.4 Results of tests and inspections for surface discontinuities including visual inspection for head bursts;

15.1.5 Results of carburization and decarburization tests;

15.1.6 Statement of compliance with dimensional and thread fit requirements;

15.1.7 Lot number and purchase order number;

15.1.8 Complete mailing address of responsible party; and

15.1.9 Title and signature of the individual assigned certification responsibility by the company officers.

15.2 Failure to include all the required information on the test report shall be cause for rejection.

16. Responsibility

16.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.
17. Product Marking

17.1 Manufacturer’s Identification—All Type 1 and Type 3 bolts shall be marked by the manufacturer with a unique identifier to identify the manufacturer or private label distributor, as appropriate.

17.2 Grade Identification:
17.2.1 Type 1 bolts shall be marked “A 490.”
17.2.2 Type 3 bolts shall be marked “A 490” underlined.

17.3 Marking Location and Methods—All marking shall be located on the top of the bolt head and shall be either raised or depressed at the manufacturer’s option.

17.4 Acceptance Criteria—Bolts that are not marked in accordance with these provisions shall be considered nonconforming and subject to rejection.

17.5 Type and manufacturer’s or private label distributor’s identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

18. Packaging and Package Marking

18.1 Packaging:
18.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.
18.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

18.2 Package Marking:
18.2.1 Each shipping unit shall include or be plainly marked with the following information:
18.2.1.1 ASTM designation and type,
18.2.1.2 Size,
18.2.1.3 Name and brand or trademark of the manufacturer,
18.2.1.4 Number of pieces,
18.2.1.5 Lot number,
18.2.1.6 Purchase order number, and
18.2.1.7 Country of origin.

SUMMARY OF CHANGES

Committee F16 has identified the location of selected changes to this standard since the last issue, A 490–02, that may impact the use of this standard. (Approved Jan. 1, 2004.)

1) Revised 6.2.1 to include compliance with the maximum tensile values to align with Tables 4 and 5.
2) In 7.2.1, changed “as” to “no” to correct a typo.
3) Revised 9.1 to include a note recognizing that Specification F 788/F 788M nor Specification F 470 guarantees 100 % freedom from head burst.

Committee F16 has identified the location of selected changes to this standard since the last issue, A 490–00, that may impact the use of this standard. (Approved Jan. 10, 2002.)

1) Revised title to have same structure as A 325.
2) In 1.1, 1.4, 1.5, 1.3.1, and 8.1.1 used wording limiting specification to heavy hex structural bolts only.
3) In 1.3, “Description of Types” and throughout the specification, deleted Table 2, “Low Carbon Martensite Steel,” because of low use and potential for misapplication.
4) Deleted the former Section 3, Terminology, because the terms are covered in Specification F 1789.
5) In 3.1.3, “Ordering Information,” specified that thread lengths shall not be changed.
6) Added 3.4 covering requirements for compressible washer-type direct tension indicators when used.
7) In 4.1 “Heat Treatment,” mandated that Type 3 bolts be quenched in oil.
8) In 4.3, deleted the reason for prohibiting metallic coatings. Not proper specification information.
9) Revised 5.3 to permit product analyses to be made by manufacturers and other entities.
10) In 5.4 add a statement requiring heats be certified as not containing intentionally added free machining elements.
11) In Table 3, “Hardness,” increased the max. hardness from 38 to 39 Rockwell C.
12) In 6.2.1, 6.2.2, and 6.2.3, revised the size and length break points for wedge testing, machined specimen testing, and axial testing.
13) In 6.2.1, changed proof load testing from “when specified” to “mandatory.”
14) In Tables 4 and 5, “Tensile Strength,” increased the max. tensile strength from 170 000 psi to 173 000 psi. Also recalculated the max. lbf values in Table 4, column 4.
15) Expanded section 7, “Carburization,” to include decarburization. Deleted the test details and referenced SAE J121 for requirements and procedure. Added reference to E 384 for microhardness tests.
16) In 8.1.1, changed the dimensional reference from B18.2.1 to B18.2.6.
17) In 8.1.2, prohibited changing the thread/grip lengths from those specified in B18.2.6.
18) Sections 10.1.1 through 10.4.1, “Magnetic Particle Inspection,” revised to make the following changes:
   Deleted Method 1 for magnetic particle inspection. Discontinued
   In 10.2.2, added reference to Practice E 1444 for magnetic particle inspection.
   In 10.2.3, added liquid penetrant inspection as an alternate
to 100% magnetic particle inspection, the same as permitted for eddy current inspection.

In Table 6, “Sample Size for Magnetic Particle Inspection,” deleted reference to MIL-STD-105.

(19) The former 13.5, “Head Bursts,” was deleted and the requirements included in 9.1 surface discontinuities applying the limits and inspection requirement of F 788/F 788M.

(20) Sections 11.1 through 11.5, “Number of Tests,” revised as follows:

   Deleted the Shipping Lot Method and made the Production Lot Method mandatory.

   In 11.4, revised the definition of the Production Lot Method to agree with FAP-1.

   In 11.5.1, referenced F 1470 mechanical properties testing frequency.

   In 11.5.1, referenced B18.2.6 as the defining standard for dimensional and thread fit testing frequency.

(21) In 13, “Inspection,” added wording to make the requirement applicable to distributors.

(22) In 14, “Rejection and Rehearing,” referenced F 1470 mechanical properties testing frequency.

(23) In 15, Certification, revised to itemize test results and other data to be included.

(24) Deleted Appendix X1, “Effect of Hot Dip Zinc Coating on the Strength of Steels,” because it is incomplete and subject to misinterpretation.
Standard Specification for High-Strength Steel Bolts, Classes 10.9 and 10.9.3, for Structural Steel Joints [Metric]

This standard is issued under the fixed designation A 490M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers two types of quenched and tempered alloy steel, metric heavy hex structural bolts having a tensile strength of 1040 to 1210 MPa.

1.2 These bolts are intended for use in structural connections comparable to those covered under the requirements of the Specification for Structural Joints Using ASTM A 325 and A 490 bolts, approved by the Research Council on Structural Connections; endorsed by the American Institute of Steel Construction and by the Industrial Fastener Institute. 2

1.3 The bolts are furnished in nominal bolt diameters M12 to M36, inclusive. They are designated by type denoting chemical composition as follows:

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>Medium carbon alloy steel</td>
</tr>
<tr>
<td>Type 2</td>
<td>Withdrawn in 2002</td>
</tr>
<tr>
<td>Type 3</td>
<td>Weathering steel</td>
</tr>
</tbody>
</table>

1.4 This specification is applicable to metric heavy hex structural bolts and alternate designs as established by the Research Council in its publication, Specification for Structural Joints Using ASTM A 325 and A 490 bolts.

1.5 For inch-pound bolts, see Specification A 490.

1.6 The following safety hazards caveat pertains only to the Test Methods portion, Section 13, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards: 3
A 325 Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
A 490 Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength
A 563M Specification for Carbon and Alloy Steel Nuts [Metric]
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
D 3951 Practice for Commercial Packaging
E 384 Test Method for Microindentation Hardness of Materials
E 709 Guide for Magnetic Particle Examination
E 1444 Practice for Magnetic Particle Inspection
F 436M Specification for Hardened Steel Washers [Metric]
F 568M Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners [Metric]
F 606M Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets [Metric]
F 788/F 788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series
F 959M Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners [Metric]
F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
F 1789 Terminology for F16 Mechanical Fasteners
2.2 ASME Standards: 4
D 3951 Practice for Commercial Packaging
E 384 Test Method for Microindentation Hardness of Materials
E 709 Guide for Magnetic Particle Examination
E 1444 Practice for Magnetic Particle Inspection
F 436M Specification for Hardened Steel Washers [Metric]
F 568M Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners [Metric]
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F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
F 1789 Terminology for F16 Mechanical Fasteners

3 For referenced ASTM standards, visit the ASTM webbiset, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard’s Document Summary page on the ASTM webbiset.

4 Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

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TABLE 1 Chemical Requirements for Type 1 Bolts

<table>
<thead>
<tr>
<th>Element</th>
<th>Heat Analysis, %</th>
<th>Product Analysis, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>0.20–0.53</td>
<td>0.19–0.55</td>
</tr>
<tr>
<td>Manganese, min</td>
<td>0.40</td>
<td>0.37</td>
</tr>
<tr>
<td>Phosphorus, max</td>
<td>0.035</td>
<td>0.040</td>
</tr>
<tr>
<td>Sulfur, max</td>
<td>0.040</td>
<td>0.045</td>
</tr>
<tr>
<td>Copper</td>
<td>0.20–0.60</td>
<td>0.17–0.83</td>
</tr>
<tr>
<td>Chromium, min</td>
<td>0.45</td>
<td>0.42</td>
</tr>
<tr>
<td>Nickel, min</td>
<td>0.20</td>
<td>0.17</td>
</tr>
<tr>
<td>Molybdenum, min</td>
<td>0.15</td>
<td>0.14</td>
</tr>
</tbody>
</table>

TABLE 2 Chemical Requirements for Type 3 Bolts

<table>
<thead>
<tr>
<th>Element</th>
<th>Heat Analysis, %</th>
<th>Product Analysis, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>0.30–0.53</td>
<td>0.28–0.55</td>
</tr>
<tr>
<td>Manganese, min</td>
<td>0.40</td>
<td>0.37</td>
</tr>
<tr>
<td>Phosphorus, max</td>
<td>0.040</td>
<td>0.045</td>
</tr>
<tr>
<td>Sulfur, max</td>
<td>0.040</td>
<td>0.045</td>
</tr>
<tr>
<td>Copper</td>
<td>0.20–0.53</td>
<td>0.17–0.83</td>
</tr>
<tr>
<td>Chromium, min</td>
<td>0.45</td>
<td>0.42</td>
</tr>
<tr>
<td>Nickel, min</td>
<td>0.20</td>
<td>0.17</td>
</tr>
<tr>
<td>Molybdenum, min</td>
<td>0.15</td>
<td>0.14</td>
</tr>
</tbody>
</table>

B1.13M Metric Screw Threads
B18.2.3.7M Metric Heavy Hex Structural Bolts
B18.24.1 Part Identifying Number (PIN) Code System

2.3 ISO Standards:

4.2 Recommended Nuts

4.2.1 Nuts conforming to the requirements of Specification A 563M are the recommended nuts for use with Specification A 490M heavy hex structural bolts. The nuts shall be of the class and have a surface finish for each type of bolt as follows.

Bolt Type and Finish | Nut Class and Finish |
---------------------|----------------------|
1, plain (uncoated) | A 563M—10S, 10S3, plain (uncoated) |
3, weathering steel | A 563M—10S3, weathering steel |

4.3 Recommended Washers

4.3.1 Washers conforming to Specification F 436M are the recommended washers for use with Specification F 490M heavy hex structural bolts. The washers shall have a surface finish for each type of bolt as follows.

Bolt Type and Finish | Washer Finish |
---------------------|---------------|
1, plain (uncoated) | plain (uncoated) |
3, weathering steel | weathering steel |

4.4 Other Accessories

4.4.1 When compressible washer type tension indicators are specified to be used with these bolts, they shall conform to Specification F 959M, Type 10.9.

5. Materials and Manufacture

5.1 Heat Treatment—Type 1 and Type 3 bolts shall be heat treated by quenching in oil from the austenitic temperature and then tempered by reheating to a temperature of not less than 425°C.

5.2 Threading—The threads shall be cut or rolled.

5.3 Protective Coatings—The bolts shall not be coated by hot-dip zinc coating, mechanical deposition, or electroplating with zinc or other metallic coatings.

6. Chemical Composition

6.1 Type 1 bolts shall be alloy steel conforming to the chemical composition requirements in Table 1. The steel shall contain sufficient alloying elements to qualify it as an alloy steel (see Note 2).

Note 2—Steel is considered to be alloy, by the American Iron and Steel Institute, when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: manganese, 1.65 %; silicon, 0.60 %; copper, 0.60 %; or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99 %, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying elements added to obtain a desired alloying effect.

6.2 Type 3 bolts shall be weathering steel conforming to the chemical composition requirements in Table 2. See Guide G 101 for methods of estimating the atmospheric corrosion resistance of low alloy steel.

Note 2—Steel is considered to be alloy, by the American Iron and Steel Institute, when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: manganese, 1.65 %; silicon, 0.60 %; copper, 0.60 %; or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99 %, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying elements added to obtain a desired alloying effect.

6.2 Type 3 bolts shall be weathering steel conforming to the chemical composition requirements in Table 2. See Guide G 101 for methods of estimating the atmospheric corrosion resistance of low alloy steel.

6.3 Product analyses made on finished bolts representing each lot shall conform to the product analysis requirements specified in Table 1 or Table 2, as applicable.

6.4 Applications of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for bolts. Compliance with this requirement shall be based on a statement on the steel certificate indicating that these elements were not intentionally added.

6.5 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

7. Mechanical Properties

7.1 Hardness—The bolts shall conform to the hardness specified in Table 3.

7.2 Tensile Properties:

7.2.1 Except as permitted in 7.2.2 for long bolts and 7.2.3 for short bolts, nominal bolt diameters M24 and smaller having a length of \(2\frac{1}{4}D\) and longer, and nominal bolt diameters larger than M24 having a length of 3D and longer shall be wedge tested full size and shall conform to the minimum wedge tensile load, and proof load or alternative proof load specified in Table 4. The load achieved during proof load testing shall be equal to or greater than the specified proof load.

7.2.2 When the length of the bolt makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements specified in Table 5. When bolts are tested by both full-size and machined specimen methods, the full-size test shall take precedence.

7.2.3 Nominal bolt diameters M24 and smaller having a length shorter than \(2\frac{1}{4}D\) down to 2D inclusive, which cannot be wedge tensile tested shall be axially tension tested full size and shall conform to the minimum tensile load and proof load or alternate proof load specified in Table 4. The load achieved during proof load testing shall be equal to or greater than the specified proof load.

7.2.4 For bolts on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event of low hardness readings.

8. Carburization/Decarburization

8.1 Definition—This test is intended to evaluate the presence or absence of carburization and decarburization as determined by the difference in microhardness near the surface and core.

8.2 Requirements:

8.2.1 Carburization—The bolts shall show no evidence of a carburized surface when evaluated in accordance with the hardness methods established in SAE J121.

8.2.2 Decarburization—Hardness value differences shall not exceed the requirements set forth for decarburization in SAE J121 for Class 2/3H materials.

8.3 Procedure—Testing for carburization/decarburization shall be performed in accordance with the microhardness (referee) methods established in SAE J121.

9. Dimensions

9.1 Head and Body:

9.1.1 The bolts shall conform to the dimensions for heavy hex structural bolts specified in ASME B18.2.3.7M for nominal bolt diameter M16 to M36 inclusive and ISO 7412 for size M12.

9.2 Threads:

9.2.1 Threads shall Metric Coarse Thread Series as specified in ASME B1.13M, and shall have Grade 6g tolerance.

9.2.2 The thread length shall not be changed from that specified for heavy hex structural bolts in ASME B18.2.3.7M and ISO 7412 in 9.1.1. Bolts requiring thread lengths other than those required by this specification shall be ordered under Specification F 568M, Class 10.9 and 10.9.3.

10. Workmanship

10.1 The allowable limits, inspection, and evaluation of the surface discontinuities, quench cracks, forging cracks, head bursts, shear bursts, seams, folds, thread laps, voids, tool marks, nicks, and gouges shall be in accordance with Specification F 788/F 788M (see Note 3).

Note 3—Specifications F 788/F 788M and F 1470 do not guarantee 100% freedom from head bursts. Sampling is designed to provide a 95% confidence level of freedom from head bursts in any test lot. Head bursts, within the limits of Specification F 788/F 788M, are unsightly but do not affect mechanical properties or functional requirements of the bolt.

11. Magnetic Particle Inspection for Longitudinal Discontinuities and Transverse Cracks

11.1 Requirements:

11.1.1 Each sample representative of the lot shall be magnetic particle inspected for longitudinal discontinuities and transverse cracks.

11.1.2 The lot, as represented by the sample, shall be free from nonconforming bolts, as defined in 11.3, when inspected in accordance with 11.2-11.2.4.

| TABLE 3 Hardness Requirements for Bolt Sizes M12 to M36 Inclusive |
|---------------------------------|-----------------|-----------------|---------------|
| Nominal Bolt Diameter, mm       | Length \(^a\)   | Brinell min     | Brinell max   |
| M12 to M24, inclusive           | Less than 2D    | 311             | 352           |
| M24 to M36, inclusive           | 2D and longer   | ...             | 352           |

\(^a\) Heavy hex structural bolts M24 and smaller and shorter than 2D are subject only to minimum and maximum hardness. Heavy hex structural bolts larger than M24 to M36 inclusive and shorter than 3D are subject only to minimum and maximum hardness.
### Table 4: Tensile Load Requirements for Full-Size Bolts

<table>
<thead>
<tr>
<th>Nominal Bolt Diameter and Thread Pitch, mm</th>
<th>Stress Area, $A_s$ mm$^2$</th>
<th>Tensile Load, $B$ kN</th>
<th>Proof Load, $B_{proof}$ kN</th>
<th>Alternative Proof Load, $B_{alt}$ kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column 1</td>
<td>Column 2</td>
<td>Column 3</td>
<td>Column 4</td>
<td>Column 5</td>
</tr>
<tr>
<td>M12 x 1.75</td>
<td>84.3</td>
<td>87.7</td>
<td>103</td>
<td>70</td>
</tr>
<tr>
<td>M16 x 2</td>
<td>157</td>
<td>163</td>
<td>190</td>
<td>130</td>
</tr>
<tr>
<td>M20 x 2.5</td>
<td>245</td>
<td>255</td>
<td>296</td>
<td>203</td>
</tr>
<tr>
<td>M22 x 2.5</td>
<td>303</td>
<td>315</td>
<td>366</td>
<td>251</td>
</tr>
<tr>
<td>M24 x 3</td>
<td>353</td>
<td>367</td>
<td>427</td>
<td>293</td>
</tr>
<tr>
<td>M27 x 3</td>
<td>459</td>
<td>477</td>
<td>555</td>
<td>381</td>
</tr>
<tr>
<td>M30 x 3.5</td>
<td>561</td>
<td>583</td>
<td>679</td>
<td>466</td>
</tr>
<tr>
<td>M36 x 4</td>
<td>817</td>
<td>850</td>
<td>989</td>
<td>678</td>
</tr>
</tbody>
</table>

$A_s = 0.7854 \left( D - (0.9382P)^2 \right)$

where:
- $A_s = $ stress area, mm$^2$
- $D = $ nominal bolt size, mm, and
- $n = $ thread pitch, mm.

### Table 5: Tensile Strength Requirements for Specimens Machined from Bolts

<table>
<thead>
<tr>
<th>Nominal Bolt Diameter, mm</th>
<th>Tensile Strength, $B$, MPa</th>
<th>Yield Strength (0.2% offset), min, MPa</th>
<th>Elongation in 50 mm, min, %</th>
<th>Reduction of Area, min, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>M12 to M36, inclusive</td>
<td>1040</td>
<td>1210</td>
<td>940</td>
<td>14</td>
</tr>
</tbody>
</table>

### Table 6: Sample Sizes with Acceptance and Rejection Numbers for Inspection of Rejectable Longitudinal Discontinuities and Transverse Cracks

<table>
<thead>
<tr>
<th>Lot Size</th>
<th>Sample Size, $A$</th>
<th>Acceptance Number, $a$</th>
<th>Rejection Number, $b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 50</td>
<td>all</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>51 to 500</td>
<td>50</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>501 to 1200</td>
<td>80</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1201 to 3200</td>
<td>125</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>3201 to 10,000</td>
<td>200</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

*Inspect all bolts in the lot if lot size is less than sample size.*
12.1 Each lot shall be tested by the manufacturer prior to shipment in accordance with the lot identification control quality assurance plan in 12.2-12.5.

12.1.1 When bolts are furnished by a source other than the manufacturer, the Responsible Party as defined in 18.1 shall be responsible for assuring all tests have been performed and the bolts comply with the requirements of this specification.

12.2 Purpose of Lot Inspection—The purpose of a lot inspection program shall be to ensure that each lot as represented by the samples tested conforms to the requirements of this specification. For such a plan to be fully effective, it is essential that secondary processors, distributors, and purchasers maintain the identification and integrity of each lot until the product is installed.

12.3 Lot Method—All bolts shall be processed in accordance with a lot identification-control quality assurance plan. The manufacturer, secondary processors, and distributors shall identify and maintain the integrity of each lot of bolts from raw-material selection through all processing operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

12.4 Lot Definition:

12.4.1 Standard Lot—A lot shall be a quantity of uniquely identified heavy hex structural bolts of the same nominal bolt diameter and length produced consecutively at the initial operation from a single mill heat of material and processed at one time, by the same process, in the same manner, so that statistical sampling is valid. The identity of the lot and lot integrity shall be maintained throughout all subsequent operations and packaging.

12.5 Number of Tests:

12.5.1 The minimum number of tests from each lot for the tests specified below shall be as follows:

<table>
<thead>
<tr>
<th>Tests</th>
<th>Number of Tests in Accordance with</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness, tensile strength, proof load</td>
<td>Guide F 1470</td>
</tr>
<tr>
<td>Surface discontinuities</td>
<td>Specification F 788/F 788M</td>
</tr>
<tr>
<td>Magnetic particle inspection</td>
<td>Table 6</td>
</tr>
<tr>
<td>Dimensions and thread fit</td>
<td>ASME B18.2.3.7M and ASME B1.13M</td>
</tr>
</tbody>
</table>

12.5.2 For carburization and decarburization tests, not less than one sample unit per manufactured lot shall be tested for microhardness.

13. Test Methods

13.1 Tensile, Proof Load, and Hardness:

13.1.1 Tensile, proof load, and hardness tests shall be conducted in accordance with Test Methods F 606M.

13.1.2 Tensile strength shall be determined using the Wedge or Axial Tension Testing Method of Full Size Product Method or the Machined Test Specimens Method, depending on size and length as specified in 7.2.1-7.2.4. Fracture on full-size tests shall be in the body or threads of the bolt without a fracture at the junction of the head and body.

13.1.3 Proof load shall be determined using Method 1, Length Measurement, or Method 2, Yield Strength, at the option of the manufacturer.

13.2 Carburization/Decarburization—Tests shall be conducted in accordance with SAE J121 Hardness Method.

13.3 Microhardness—Tests shall be conducted in accordance with Test Method E 384.

13.4 Magnetic Particle—Inspection shall be conducted in accordance with Section 11.

14. Inspection

14.1 If the inspection described in 14.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

14.2 The purchaser’s representative shall have free entry to all parts of manufacturer’s works or supplier’s place of business that concern the manufacture of the material ordered. The manufacturer or supplier shall afford the purchaser’s representative all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser’s representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the manufacturer’s works or supplier’s place of business.

15. Rejection and Rehearing

15.1 Disposition of nonconforming bolts shall be in accordance with the section titled “Disposition of Nonconforming Lots” in Guide F 1470.

16. Certification

16.1 When specified on the purchase order, the manufacturer or supplier, whichever is the responsible party as defined in Section 17, shall furnish the purchaser a test report that includes the following:

16.1.1 Heat analysis, heat number, and a statement certifying that heats having bismuth, selenium, tellurium, or lead intentionally added were not used to produce the bolts;

16.1.2 Results of hardness, tensile, and proof load tests;

16.1.3 Results of magnetic particle inspection for longitudinal discontinuities and transverse cracks;

16.1.4 Results of tests and inspections for surface discontinuities including visual inspection for head bursts;

16.1.5 Results of carburization and decarburization tests;

16.1.6 Statement of compliance with dimensional and thread fit requirements;

16.1.7 Lot number and purchase order number;

16.1.8 Complete mailing address of responsible party; and

16.1.9 Title and signature of the individual assigned certification responsibility by the company officers.

16.2 Failure to include all the required information on the test report shall be cause for rejection.

17. Responsibility

17.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.
18. Product Marking

18.1 Manufacturer’s Identification—All Type 1 and Type 3 bolts shall be marked by the manufacturer with a unique identifier to identify the manufacturer or private label distributor, as appropriate.

18.2 Grade Identification:
18.2.1 Type 1 bolts shall be marked “A 490M.”
18.2.2 Type 3 bolts shall be marked “A 490M” underlined. The use of additional distinguishing marks to indicate the bolts are weathering steel shall be at the manufacturer’s option.

18.3 Marking Location and Methods—All marking shall be located on the top of the bolt head and shall be either raised or depressed at the manufacturer’s option.

18.4 Acceptance Criteria—Bolts that are not marked in accordance with these provisions shall be considered non-conforming and subject to rejection.

18.5 Type and manufacturer’s or private label distributor’s identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

19. Packaging and Package Marking

19.1 Packaging:
19.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.
19.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

19.2 Package Marking:
19.2.1 Each shipping unit shall include or be plainly marked with the following information:
19.2.1.1 ASTM designation and type,
19.2.1.2 Size, including nominal bolt diameter, thread pitch, and bolt length,
19.2.1.3 Name and brand or trademark of the manufacturer,
19.2.1.4 Number of pieces,
19.2.1.5 Lot number,
19.2.1.6 Purchase order number, and
19.2.1.7 Country of origin.

20. Keywords
20.1 alloy steel; bolts; metric; SI; steel; structural; weathering steel

SUMMARY OF CHANGES

Committee F16 has identified the location of selected changes to this standard since the last issue, A 490M–03, that impact the use of this standard. (Approved Jan. 1, 2004.)

(I) Revised Section 9.1 to include a note recognizing that Specification F 788/F 788M nor Specification F 1470 guarantee 100 % freedom from head burst.

Committee F16 has identified the location of selected changes to this standard since the last issue, A 490M–00, that may impact the use of this standard. (Approved May 10, 2003.)

(I) Overall revision to make the specification self standing without reliance on Specification F 568M, and in general align with Specification A 490 (except metric).
1. Scope

1.1 This specification covers three grades of steel rivets in diameters from ½ to 1½ in. inclusive, for structural fabricating purposes. The grades are as follows:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Carbon steel rivets for general purpose use</td>
</tr>
<tr>
<td>2</td>
<td>Carbon manganese steel rivets for use with high strength carbon and high strength low alloy structural steels</td>
</tr>
<tr>
<td>3</td>
<td>Weathering steel rivets</td>
</tr>
</tbody>
</table>

1.2 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:
   - A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
   - D 3951 Practice for Commercial Packaging
   - F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
   - F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

2.2 ASME Standard:
   - B 18.1.2 Large Rivets (½ Inch Nominal Diameter and Larger)

3. Ordering Information

3.1 Orders for rivets under this specification shall include:
   - 3.1.1 Quantity (number of pieces of rivets),
   - 3.1.2 Name of product, including head type,
   - 3.1.3 Dimensions including nominal diameter and length,
   - 3.1.4 Supplementary Requirement S1, if required (see 8.1.2),
   - 3.1.5 Test report, if required (see 14.1),
   - 3.1.6 Additional package marking, if required (see 17.2),
   - 3.1.7 ASTM designation, including grade and date of issue, and
   - 3.1.8 Any special requirements.

Example—10 000 pieces, Steel Button Head Rivets, ½ × 1 in., Test Report Required, ASTM A 502, Grade 1, dated____ .

4. Materials and Manufacture

4.1 Process—The steel for rivets shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

4.2 Heading—Rivets shall be made by the hot or cold heading process. It is expected that these rivets ordinarily will be hot driven.

5. Chemical Composition

5.1 Grade 1 and Grade 2 rivets shall conform to the heat analysis requirements given in Table 1.

5.2 Grade 3 rivets shall be weathering steel and shall conform to Class A or Class B chemical composition specified in Table 1. The selection of the composition, A or B, shall be at the option of the rivet manufacturer. See Guide G 101 for methods of estimating the atmospheric corrosion resistance of low alloy steels.

5.3 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted. Compliance with this requirement shall be based on a statement on the steel certificate indicating that these elements were not intentionally added.

5.4 Product analysis made on finished rivets representing each lot shall conform to the product analysis requirements specified in Table 1, as applicable. Product Analysis is not applicable to Grade 1 rivets made from rimmed steel or merchant quality bars.

6. Mechanical Properties

6.1 The rivets shall conform to the hardness requirements shown in Table 2.
6.2 Brinell hardness shall be measured at only one point. Rockwell hardness shall be measured at three points, equally spaced about the axis of the rivet, and the hardness shall be taken as the arithmetic average of the three measurements.

7. Dimensions

7.1 Dimensions of rivets, unless otherwise specified, shall conform to those of one of the head types provided in ASME B 18.1.2.

8. Number of Tests and Retests

8.1 Hardness:

8.1.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified hardness requirements. Additional tests of individual shipments of material are not ordinarily contemplated. Individual heats of steel are not necessarily identified in the finished product.

8.1.2 Additional hardness tests of individual shipments of rivets are not ordinarily required. When required, Supplementary Requirement S1 shall be specified.

8.2 Head Bursts and Duds:

8.2.1 From each lot, the number of tests and the acceptance/rejection criteria for cracks (bursts) and duds shall be in accordance with Guide F 1470 using the sampling level characteristic specified for Surface Discontinuities.

9. Specimen Preparation

9.1 Rivets used for testing shall be heat treated in the following manner prior to testing:

9.1.1 Grade 1—Normalize by air cooling from above the transformation range.

9.1.2 Grade 2—Anneal by heating to 1450°F (790°C), holding for 30 min at temperature and cooling in the furnace.

9.1.3 Grade 3—Normalizing test samples shall be at the option of the manufacturer.

9.2 If any test specimen shows defective preparation, it shall be discarded and another specimen substituted.

10. Visual Inspection for Head Bursts and Duds

10.1 The rivets shall be inspected for cracks (bursts) and duds. Sampling and inspection shall be in accordance with 8.2. Rivets having an opening at the periphery of the head wider than 0.020 inch plus 0.05 times the rivet diameter shall be considered nonconforming (see Note 1).

9.2 If any test specimen shows defective preparation, it shall be discarded and another specimen substituted.

11. Test Methods

11.1 Hardness tests shall be conducted in accordance with Test Methods F 606.

11.2 Chemical analyses shall be conducted in accordance with Test Methods A 751.

12. Inspection

12.1 If the inspection described in 12.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

12.2 The purchaser’s representative shall have free entry to all parts of the manufacturer’s works or supplier’s place of business that concern the manufacture or supply of the rivets ordered. The manufacturer or supplier shall afford the purchaser’s representative all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser’s representative shall be made before shipment, and shall be conducted as not to
interfere unnecessarily with the operation of the manufacturer’s works or supplier’s place of business.

13. Rejection and Rehearing

13.1 Disposition of nonconforming rivets shall be in accordance with the Guide F 1470 section entitled “Disposition of Nonconforming Lots.”

14. Certification

14.1 Upon request of the purchaser in the contract or order, a manufacturer’s certification that the rivets were manufactured and tested in accordance with this specification, together with a report of the latest hardness tests of each stock size in each shipment, shall be furnished at the time of shipment.

14.2 When Supplementary Requirement S1 has been specified, and when specified on the purchase order, the manufacturer or supplier, whichever is the responsible party as defined in Section 15, shall furnish the purchaser a test report(s) that includes the following:

14.2.1 Heat analysis, heat number, and a statement certifying heats having the elements listed in 5.3 intentionally added were not used to produce the rivets,
14.2.2 Results of hardness tests,
14.2.3 Results of visual inspection for head bursts and duds,
14.2.4 Statement of compliance with dimensional requirements,
14.2.5 Lot number and purchase order number,
14.2.6 Complete mailing address of responsible party, and
14.2.7 Title and signature of the individual assigned certification responsibility by the company officers;
14.2.8 Failure to include all the required information on the test report shall be cause for rejection.

15. Responsibility

15.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

16. Product Marking

16.1 All rivets shall be marked with a symbol to identify the manufacturer or private label distributor, as appropriate.

16.2 In addition, the rivets shall be marked as follows to identify the grade.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Grade Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>none required*</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

* The numeral 1 shall be used at the manufacturer's option.

16.3 The marking shall appear on the rivet head and shall be raised or depressed at the manufacturer’s option.

16.4 Grade and manufacturer’s or private label distributor’s identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

17. Packaging and Package Marking

17.1 Packaging:
17.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.
17.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

17.2 Package Marking:
17.2.1 Each shipping unit shall include or be plainly marked with the following information:
17.2.1.1 ASTM designation and grade,
17.2.1.2 Size,
17.2.1.3 Name and brand or trademark of the manufacturer,
17.2.1.4 Number of pieces,
17.2.1.5 Purchase order number, and
17.2.1.6 Country of origin.

18. Keywords

18.1 carbon steel; rivets; steel; structural; weathering steel

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified in the purchase order or contract.

S1. Additional Hardness Tests on Individual Shipments

S1.1 When additional hardness tests on individual shipments are required, sampling and acceptance/rejection criteria shall be in accordance with Guide F 1470.
Standard Specification for Carbon and Alloy Steel Nuts

This standard is issued under the fixed designation A 563; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers chemical and mechanical requirements for eight grades of carbon and alloy steel nuts for general structural and mechanical uses on bolts, studs, and other externally threaded parts.

NOTE 1—See Appendix X1 for guidance on suitable application of nut grades.

1.2 The requirements for any grade of nut may, at the supplier’s option, and with notice to the purchaser, be fulfilled by furnishing nuts of one of the stronger grades specified herein unless such substitution is barred in the inquiry and purchase order.

1.3 Grades C3 and DH3 nuts have atmospheric corrosion resistance and weathering characteristics comparable to that of the steels covered in Specifications A 242/A 242M, A 588/A 588M, and A 709/A 709M. The atmospheric corrosion resistance of these steels is substantially better than that of carbon steel with or without copper addition (see 5.2). When properly exposed to the atmosphere, these steels can be used bare (uncoated) for many applications.

NOTE 2—A complete metric companion to Specification A 563 has been developed—A 563M; therefore, no metric equivalents are presented in this specification.

1.4 Terms used in this specification are defined in Terminology F 1789 unless otherwise defined herein.

2. Referenced Documents

2.1 ASTM Standards:

A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service, or Both
A 242/A 242M Specification for High-Strength Low-Alloy Structural Steel
A 307 Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength
A 325 Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
A 394 Specification for Steel Transmission Tower Bolts, Zinc-Coated and Bare
A 449 Specification for Quenched and Tempered Steel Bolts and Studs
A 490 Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength
A 588/A 588M Specification for High-Strength Low-Alloy Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4-in. [100-mm] Thick
A 687 Specification for High-Strength Nonheaded Steel Bolts and Studs
A 709/A 709M Specification for Carbon and High-Strength Low-Alloy Structural Steel Shapes, Plates, and Bars and Quenched-and-Tempered Alloy Structural Steel Plates for Bridges
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
D 3951 Practice for Commercial Packaging
F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
F 812/F 812M Specification for Surface Discontinuities of Nuts, Inch and Metric Series
F 1789 Terminology for F16 Mechanical Fasteners

2.2 ANSI Standards:

3 This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.02 on Steel Bolts, Nuts, Rivets, and Washers.


For ASME Boiler and Pressure Vessel Code applications see related Specification SA – 563 in Section II of that Code.

3 For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard’s Document Summary page on the ASTM website.

*A Summary of Changes section appears at the end of this standard.

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3. Ordering Information

3.1 Orders for nuts under this specification shall include the following:
   3.1.1 Quantity (number of nuts),
   3.1.2 Nominal size and thread series of nuts,
   3.1.3 Style of nut (for example, heavy hex),
   3.1.4 Grade of nut,
   3.1.5 Zinc Coating—Specify the zinc-coating process required, for example, hot-dip, mechanically deposited, or no preference (see 4.7),
   3.1.6 Other Finishes—Specify other protective finish if required,
   3.1.7 ASTM designation and year of issue, and
   3.1.8 Supplementary or special requirements.

Note 3—An example of an ordering description follows: 1000 7/8-9 heavy hex nuts, Grade DH, hot-dip zinc-coated, and lubricated, ASTM A 563-XX.

4. Materials and Manufacture

4.1 Steel for nuts shall be made by the open-hearth, basic-oxygen, or electric-furnace process except that steel for Grades O, A, and B nuts may be made by the acid-bessemer process.
4.2 Nuts may be made cold or hot by forming, pressing, or punching or may be machined from bar stock.
4.3 Grades DH and DH3 nuts shall be heat treated by quenching in a liquid medium from a temperature above the transformation temperature and tempering at a temperature of at least 800°F.
4.4 Grades C and D nuts made of steel having carbon content not exceeding 0.20 %, phosphorus not exceeding 0.04 %, and sulfur not exceeding 0.05 % by heat analysis may be heat treated by quenching in a liquid medium from a temperature above the transformation temperature and need not be tempered. When this heat treatment is used, there shall be particular attention to the requirements in 6.1.1.
4.5 Grades C, C3, and D nuts made of any steel permitted for these grades may be heat treated by quenching in a liquid medium from a temperature above the transformation temperature and tempering at a temperature of at least 800°F.
4.6 Threads shall be formed by tapping or machining.
4.7 Zinc Coatings, Hot-Dip and Mechanically Deposited:
   4.7.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc coating process, for example, hot-dip, mechanically deposited, or no preference.
   4.7.2 When hot-dip is specified, the fasteners shall be zinc-coated by the hot-dip process in accordance with the requirements of Class C, of Specification A 153.
   4.7.3 When mechanically deposited is specified, the fasteners shall be zinc coated by the mechanical deposition process in accordance with the requirements of Class 50 of Specification B 695.
4.7.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification A 153, Class C, or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process and the supplier’s option is limited to one process per item with no mixed processes in a lot.
   4.7.5 Hot-dip zinc-coated nuts shall be tapped after zinc coating.
   4.7.6 Mechanically deposited zinc-coated nuts for assembly with mechanically deposited zinc-coated bolts shall be tapped oversize prior to zinc coating and need not be retapped afterwards.

4.8 Lubricant:
   4.8.1 Hot-dip and mechanically deposited zinc-coated Grade DH nuts shall be provided with an additional lubricant which shall be clean and dry to the touch.
4.8.2 See Supplementary Requirement S2 for option to specify a dye in the lubricant.

5. Chemical Composition

5.1 Grades O, A, B, C, D, and DH shall conform to the chemical composition specified in Table 1.
5.2 Grades C3 and DH3 shall conform to the chemical composition specified in Table 2. See Guide G 101 for methods of estimating the atmospheric corrosion resistance of low alloy steels.
5.3 Resulfurized or rephosphorized steel, or both, are not subject to rejection based on product analysis for sulfur or phosphorus.
5.4 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for Grades D, DH, and DH3.
5.5 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 Hardness:
   6.1.1 The hardness of nuts of each grade shall not exceed the maximum hardness specified for the grade in Table 3.
6.1.2 Jam nuts, slotted nuts, nuts smaller in width across flats or thickness than standard hex nuts (7.1), and nuts that

<table>
<thead>
<tr>
<th>Grade of Nut</th>
<th>Chemical Requirement</th>
<th>Carbon</th>
<th>Manganese, min</th>
<th>Phosphorus, max</th>
<th>Sulfur, max</th>
</tr>
</thead>
<tbody>
<tr>
<td>O, A, B, C</td>
<td>heat product</td>
<td>0.55 max</td>
<td>...</td>
<td>0.12</td>
<td>0.15A</td>
</tr>
<tr>
<td></td>
<td>product</td>
<td>0.58 max</td>
<td>...</td>
<td>0.13а</td>
<td>...</td>
</tr>
<tr>
<td>D</td>
<td>heat product</td>
<td>0.55 max</td>
<td>0.30</td>
<td>0.04</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>product</td>
<td>0.58 max</td>
<td>0.27</td>
<td>0.048</td>
<td>0.058</td>
</tr>
<tr>
<td>DH</td>
<td>heat product</td>
<td>0.20–0.55</td>
<td>0.60</td>
<td>0.04</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>product</td>
<td>0.18–0.58</td>
<td>0.57</td>
<td>0.048</td>
<td>0.058</td>
</tr>
</tbody>
</table>

A For Grades O, A, and B a sulfur content of 0.23 % max is acceptable with the purchaser's approval.
а Acid bessemer steel only.
а For Grades D and DH a sulfur content of 0.05–0.15 % is acceptable provided the manganese is 1.35 % min.

TABLE 1 Chemical Requirements for Grades O, A, B, C, D, and DH Nuts

would require a proof load in excess of 160,000 lbf may be furnished on the basis of minimum hardness requirements specified for the grade in Table 3, unless proof load testing is specified in the inquiry and purchase order.

6.2 Proof Load:
6.2.1 Nuts of each grade, except those listed in 6.1.2, shall withstand the proof load stress specified for the grade, size, style, thread series, and surface finish of the nut in Table 3 and Table 4.

6.2.2 Nuts hot dip or mechanically zinc coated in accordance with 4.7.2 or 4.7.3 shall be proof load tested after zinc coating and overtapping.

7. Dimensions
7.1 Unless otherwise specified, nuts shall be plain (uncoated) and shall conform to the dimensions prescribed in ANSI B18.2.2.

7.2 Hex and hex-slotted nuts over 1½ to 2 in. inclusive shall have dimensions conforming to ANSI B18.2.2 calculated using the formulas for the 1 ¼ through 1½-in. size range in Appendix III (Formulas for Nut Dimensions) of ANSI B18.2.2.

7.3 Threads: Plain (Uncoated) Nuts

7.3.1 Unless otherwise specified, the threads shall conform to the dimensions for coarse threads with Class 2B tolerances prescribed in ANSI B1.1.

7.4 Threads: Nuts Hot Dip Zinc Coated per A 153 C1. C (4.7.2)

7.4.1 Nuts to be used on bolts with Class 2A threads before hot-dip zinc coating, and then hot-dip zinc coated in accordance with Specification A 153, Class C, shall be tapped oversize after coating, to the minimum and maximum thread dimensions in Table 5. The major and minor diameters shall also be increased by the allowance to provide the corresponding minimum and maximum major and minor diameters.

7.5 Threads: Nuts With Other Coatings

7.5.1 Nuts to be used on bolts mechanically zinc coated or on bolts hot-dip zinc-coated to a specification other than Specification A 153, Class C, or otherwise hot-dip coated, shall be tapped oversize by a diametral amount sufficient to permit assembly on the coated bolt thread, unless other requirements are specified in the inquiry or purchase order.

7.5.2 When specifically permitted by the purchaser, nuts for bolts with electrodeposited coating, such as cadmium, zinc, and so forth, or with chemically applied coating may be tapped.

 TABLE 2 Chemical Requirements for Grades C3 and DH3 Nuts

<table>
<thead>
<tr>
<th>Element</th>
<th>Composition, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Classes for Grade C 3 Nuts(^A)</td>
</tr>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Carbon:</td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td></td>
</tr>
<tr>
<td>Product analysis</td>
<td></td>
</tr>
<tr>
<td>Manganese:</td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td></td>
</tr>
<tr>
<td>Product analysis</td>
<td></td>
</tr>
<tr>
<td>Phosphorus:</td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.07–0.15</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.07–0.155</td>
</tr>
<tr>
<td>Sulfer:</td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.050 max</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.055 max</td>
</tr>
<tr>
<td>Silicon:</td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.20–0.90</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.15–0.95</td>
</tr>
<tr>
<td>Copper:</td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.25–0.55</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.22–0.58</td>
</tr>
<tr>
<td>Nickel:</td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>1.00 max</td>
</tr>
<tr>
<td>Product analysis</td>
<td>1.03 max</td>
</tr>
<tr>
<td>Chromium:</td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.30–1.25</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.25–1.30</td>
</tr>
<tr>
<td>Vanadium:</td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td></td>
</tr>
<tr>
<td>Product analysis</td>
<td></td>
</tr>
<tr>
<td>Molybdenum:</td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td></td>
</tr>
<tr>
<td>Product analysis</td>
<td></td>
</tr>
<tr>
<td>Titanium:</td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td></td>
</tr>
<tr>
<td>Product analysis</td>
<td></td>
</tr>
</tbody>
</table>

\(^A\) C3 nuts may be made of any of the above listed material classes. Selection of the class shall be at the option of the manufacturer.

\(^B\) Nickel or molybdenum may be used.
oversize by a diametral amount sufficient to permit assembly on the coated bolt thread.

7.5.3 The allowable oversize tapping shall not exceed that specified in Table 5.

8. Workmanship

8.1 Surface discontinuity limits shall be in accordance with Specification F 812/F 812M.

9. Number of Tests

9.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of

### TABLE 3 Mechanical Requirements

<table>
<thead>
<tr>
<th>Grade of Nut</th>
<th>Nominal Nut Size, in.</th>
<th>Style of Nut</th>
<th>Proof Load Stress, ksi</th>
<th>Brinell Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Non-Zinc-Coated Nuts&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Zinc-Coated Nuts&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>min</td>
<td>max</td>
</tr>
<tr>
<td>A</td>
<td>¼ to ½</td>
<td>hex</td>
<td>69</td>
<td>52</td>
</tr>
<tr>
<td>B</td>
<td>¼ to ½</td>
<td>hex</td>
<td>90</td>
<td>68</td>
</tr>
<tr>
<td>C</td>
<td>¼ to ½</td>
<td>hex</td>
<td>120</td>
<td>90</td>
</tr>
<tr>
<td>D</td>
<td>¼ to ½</td>
<td>hex</td>
<td>105</td>
<td>79</td>
</tr>
<tr>
<td>DH&lt;sup&gt;o&lt;/sup&gt;</td>
<td>¼ to ½</td>
<td>hex</td>
<td>135</td>
<td>135</td>
</tr>
<tr>
<td>DH3</td>
<td>½ to 1</td>
<td>hex</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>A</td>
<td>¼ to 4</td>
<td>heavy hex</td>
<td>100</td>
<td>75</td>
</tr>
<tr>
<td>B</td>
<td>¼ to 1</td>
<td>heavy hex</td>
<td>133</td>
<td>100</td>
</tr>
<tr>
<td>C</td>
<td>⅛ to ⅜</td>
<td>heavy hex</td>
<td>116</td>
<td>87</td>
</tr>
<tr>
<td>D</td>
<td>¼ to 4</td>
<td>hex</td>
<td>144</td>
<td>144</td>
</tr>
<tr>
<td>DH&lt;sup&gt;o&lt;/sup&gt;</td>
<td>¼ to 4</td>
<td>hex</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>DH3</td>
<td>¼ to 4</td>
<td>hex</td>
<td>175</td>
<td>150</td>
</tr>
<tr>
<td>A</td>
<td>¼ to 1½</td>
<td>hex thick</td>
<td>100</td>
<td>75</td>
</tr>
<tr>
<td>B</td>
<td>¼ to 1½</td>
<td>hex thick</td>
<td>133</td>
<td>100</td>
</tr>
<tr>
<td>B1</td>
<td>⅛ to ⅜</td>
<td>hex thick</td>
<td>116</td>
<td>87</td>
</tr>
<tr>
<td>D</td>
<td>¼ to 4</td>
<td>hex thick</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>DH&lt;sup&gt;o&lt;/sup&gt;</td>
<td>¼ to 4</td>
<td>hex thick</td>
<td>175</td>
<td>175</td>
</tr>
</tbody>
</table>

<sup>a</sup>To determine nut proof load in pounds, multiply the appropriate nut proof load stress by the tensile stress area of the thread. Stress areas for UNC, UNF, and 8 UN thread series are given in Table 4.

<sup>b</sup>Non-zinc-coated nuts are nuts intended for use with externally threaded fasteners which have a plain (nonplated or noncoated) finish or have a plating or coating of insufficient thickness to necessitate overtapping the nut thread to provide assemblability. Zinc-coated nuts are nuts intended for use with externally threaded fasteners which are hot-dip zinc-coated, mechanically zinc-coated, or have a plating or coating of sufficient thickness to necessitate overtapping the nut thread to provide assemblability.

<sup>c</sup>Nuts made in accordance to the requirements of Specification A 194/A 194M, Grade 2 or Grade 2H, and marked with their grade symbol are acceptable equivalents for Grades C and D nuts. When A 194 zinc-coated inch series nuts are supplied, the zinc coating, overtapping, lubrication and rotational capacity testing shall be in accordance with Specification A 563.

<sup>d</sup>Nuts made in accordance with the requirements of Specification A 194/A 194M, Grade 2H, and marked with its grade symbol are an acceptable equivalent for Grade DH nuts. When A 194 zinc-coated inch series nuts are supplied, the zinc coating, overtapping, lubrication and rotational capacity testing shall be in accordance with Specification A 563.

---

4
9.2 When additional tests are specified in the inquiry and purchase order, a lot, for purposes of selecting test samples, shall consist of all material offered for inspection at one time purchased. Individual heats of steel are not identified in the finished product.

9.3 Unless otherwise specified in the inquiry and purchase order, the number of tests for each lot of required property shall be as follows:

<table>
<thead>
<tr>
<th>Number of Nuts in Lot</th>
<th>Number of Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and under</td>
<td>1</td>
</tr>
<tr>
<td>801 to 8 000</td>
<td>2</td>
</tr>
<tr>
<td>8 001 to 20 000</td>
<td>3</td>
</tr>
<tr>
<td>Over 20 000</td>
<td>5</td>
</tr>
</tbody>
</table>

9.4 If any test specimen shows flaws, it may be discarded and another specimen substituted.

9.5 Should any specimen fail to meet the requirements of any specified test, double the number of specimens from the same lot shall be tested for this property, in which case all of the additional specimens shall meet the specifications.

10. Test Methods

10.1 Tests shall be conducted in accordance with Test Methods F 606.

11. Report

11.1 When specified in the order, the manufacturer shall furnish a test report certified to be the last completed set of mechanical tests for each stock size in each shipment.

12. Inspection

12.1 If the inspection described in 12.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

12.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser’s representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of

---

**TABLE 4 Tensile Stress Areas**

<table>
<thead>
<tr>
<th>Nominal Size–Threads per Inch</th>
<th>UNC Nominal Size–Threads per Inch</th>
<th>UNF Nominal Size–Threads per Inch</th>
<th>8 UN Nominal Size–Threads per Inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>¼ –20</td>
<td>0.0318</td>
<td>0.0364</td>
<td>...</td>
</tr>
<tr>
<td>¾ –18</td>
<td>0.0524</td>
<td>0.0580</td>
<td>...</td>
</tr>
<tr>
<td>½ –16</td>
<td>0.0775</td>
<td>0.0878</td>
<td>...</td>
</tr>
<tr>
<td>⅛ –14</td>
<td>0.1063</td>
<td>0.1187</td>
<td>...</td>
</tr>
<tr>
<td>¼ –13</td>
<td>0.1419</td>
<td>0.1599</td>
<td>...</td>
</tr>
<tr>
<td>⅛ –12</td>
<td>0.182</td>
<td>0.203</td>
<td>...</td>
</tr>
<tr>
<td>⅛ –11</td>
<td>0.226</td>
<td>0.256</td>
<td>...</td>
</tr>
<tr>
<td>⅛ –10</td>
<td>0.334</td>
<td>0.373</td>
<td>...</td>
</tr>
<tr>
<td>⅛ –9</td>
<td>0.482</td>
<td>0.509</td>
<td>...</td>
</tr>
<tr>
<td>1–8</td>
<td>0.606</td>
<td>0.663</td>
<td>1–8</td>
</tr>
<tr>
<td>1⅛ –7</td>
<td>0.763</td>
<td>0.856</td>
<td>1⅛ –8</td>
</tr>
<tr>
<td>1⅝ –6</td>
<td>0.969</td>
<td>1.073</td>
<td>1⅝ –8</td>
</tr>
<tr>
<td>1½ –5</td>
<td>1.155</td>
<td>1.315</td>
<td>1½ –6</td>
</tr>
<tr>
<td>1⅝ –4</td>
<td>1.405</td>
<td>1.581</td>
<td>1⅝ –5</td>
</tr>
<tr>
<td>2–4½</td>
<td>1.90</td>
<td>...</td>
<td>2–4½</td>
</tr>
<tr>
<td>2½ –4½</td>
<td>2.50</td>
<td>...</td>
<td>2½ –4½</td>
</tr>
<tr>
<td>2⅛ –4</td>
<td>3.25</td>
<td>...</td>
<td>2⅛ –4</td>
</tr>
<tr>
<td>2⅝ –4</td>
<td>4.00</td>
<td>...</td>
<td>2⅝ –4</td>
</tr>
<tr>
<td>3–4</td>
<td>4.93</td>
<td>...</td>
<td>3–4</td>
</tr>
<tr>
<td>3½ –4</td>
<td>5.97</td>
<td>...</td>
<td>3½ –4</td>
</tr>
<tr>
<td>4–4</td>
<td>7.10</td>
<td>...</td>
<td>4–4</td>
</tr>
<tr>
<td>4–4</td>
<td>11.08</td>
<td>...</td>
<td>4–4</td>
</tr>
</tbody>
</table>

The stress area is calculated as follows:

\[ A_s = 0.7854 \left( D - \frac{0.9743}{n} \right)^2 \]

where:

- \( A_s \) = stress area, in.²
- \( D \) = nominal size, in.
- \( n \) = threads per inch.

**TABLE 5 Thread Dimensions and Overtapping Allowances for Nuts Hot Dip Zinc Coated per Specification A 153, C1. C**

<table>
<thead>
<tr>
<th>Nominal Nut Size, in. and Pitch</th>
<th>Diametral Allowance, in.⁴</th>
<th>Pitch Diameter, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.250-20</td>
<td>0.016</td>
<td>0.2335</td>
</tr>
<tr>
<td>0.312-18</td>
<td>0.017</td>
<td>0.2934</td>
</tr>
<tr>
<td>0.375-16</td>
<td>0.017</td>
<td>0.3514</td>
</tr>
<tr>
<td>0.437-14</td>
<td>0.018</td>
<td>0.4091</td>
</tr>
<tr>
<td>0.500-13</td>
<td>0.018</td>
<td>0.4680</td>
</tr>
<tr>
<td>0.562-12</td>
<td>0.020</td>
<td>0.5284</td>
</tr>
<tr>
<td>0.625-11</td>
<td>0.020</td>
<td>0.5860</td>
</tr>
<tr>
<td>0.750-10</td>
<td>0.020</td>
<td>0.7050</td>
</tr>
<tr>
<td>0.875-9</td>
<td>0.022</td>
<td>0.8248</td>
</tr>
<tr>
<td>1.000-8</td>
<td>0.024</td>
<td>0.9428</td>
</tr>
<tr>
<td>1.125-8</td>
<td>0.024</td>
<td>1.0678</td>
</tr>
<tr>
<td>1.125-7</td>
<td>0.024</td>
<td>1.0562</td>
</tr>
<tr>
<td>1.250-8</td>
<td>0.024</td>
<td>1.1928</td>
</tr>
<tr>
<td>1.250-7</td>
<td>0.024</td>
<td>1.1812</td>
</tr>
<tr>
<td>1.375-8</td>
<td>0.027</td>
<td>1.3206</td>
</tr>
<tr>
<td>1.375-7</td>
<td>0.027</td>
<td>1.2937</td>
</tr>
<tr>
<td>1.500-8</td>
<td>0.027</td>
<td>1.4458</td>
</tr>
<tr>
<td>1.500-7</td>
<td>0.027</td>
<td>1.4187</td>
</tr>
<tr>
<td>1.750-5</td>
<td>0.050</td>
<td>1.6701</td>
</tr>
<tr>
<td>2.000-4.5</td>
<td>0.050</td>
<td>1.9057</td>
</tr>
<tr>
<td>2.250-4.5</td>
<td>0.050</td>
<td>2.1557</td>
</tr>
<tr>
<td>2.500-4</td>
<td>0.050</td>
<td>2.3876</td>
</tr>
<tr>
<td>2.750-4</td>
<td>0.050</td>
<td>2.6376</td>
</tr>
<tr>
<td>3.000-4</td>
<td>0.050</td>
<td>2.8678</td>
</tr>
<tr>
<td>3.250-4</td>
<td>0.050</td>
<td>3.1376</td>
</tr>
<tr>
<td>3.500-4</td>
<td>0.050</td>
<td>3.3876</td>
</tr>
<tr>
<td>3.750-4</td>
<td>0.050</td>
<td>3.6376</td>
</tr>
<tr>
<td>4.000-4</td>
<td>0.050</td>
<td>3.8876</td>
</tr>
</tbody>
</table>

These allowances also apply to the minimum and maximum major and minor diameters.

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A Italicized text.
dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

14. Product Marking

14.1 Nuts made to the requirements of Grades O, A, and B are not required to be marked unless individual marking is specified in the inquiry and order. When individual marking is required, the mark shall be the grade letter symbol on one face of the nut.

14.2 Heavy hex nuts made to the requirements of Grade C (Note 4) shall be marked on one face with three circumferential marks 120° apart.

14.3 Heavy hex nuts made to the requirements of Grade C3 shall be marked on one face with three circumferential marks 120° apart and the numeral 3. In addition, the manufacturer may add other distinguishing marks indicating that the nut is atmospheric corrosion resistant and of a weathering type.

14.4 Nuts made to the requirements of Grade D shall be marked with the grade symbol, D (Note 4) on one face.

14.5 Nuts made to the requirements of Grade DH shall be marked with the grade symbol, DH (Note 4) on one face.

14.6 Heavy hex nuts made to the requirements of Grade DH3 shall be marked with the grade symbol DH3 on one face. Hex nuts made to the requirements of DH3 shall be marked with the symbol HX3 on one face. In addition, the manufacturer may add other distinguishing marks indicating that the nut is atmospheric corrosion resistant and of a weathering type.

14.7 In addition, nuts of Grades C, C3, D, DH, and DH3 and hex nuts made to the requirements of DH3, shall be marked with a symbol to identify the manufacturer or private label distributor, as appropriate.

14.8 Marks may be raised or depressed at the option of the manufacturer. However, if markings are located on the bearing surface, they shall be depressed.

14.9 Grade and manufacturer’s or private label distributor’s identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

NOTE 4—See Table 3 for marking of equivalent nuts made in accordance with requirements of Specification A 194/A 194M.

15. Packaging and Package Marking

15.1 Packaging:

15.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

15.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

15.2 Package Marking:

15.2.1 Each shipping unit shall include or be plainly marked with the following information:

15.2.1.1 ASTM designation and grade,

15.2.1.2 Size,

15.2.1.3 Name and brand or trademark of the manufacturer,

15.2.1.4 Number of pieces,

15.2.1.5 Purchase order number, and

15.2.1.6 Country of origin.

16. Responsibility

16.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with the specification and meets all of its requirements.

17. Keywords

17.1 alloy steel; carbon steel; nuts; steel; weathering steel

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall be applied only when specified by the purchaser on the contract or order. Details of these supplementary requirements shall be agreed upon in writing between the manufacturer and purchaser. This supplementary requirement shall in no way negate any requirement of the specification itself.

S1. Lubricant and Rotational Capacity Test for Coated Nuts

S1.1 Nuts shall be provided with an additional lubricant that shall be clean and dry to the touch.

S1.2 Rotational capacity test procedures, nut rotations, and acceptance criteria are a function of the bolt with which the nuts will be used. They are covered by the applicable bolt specification.

S2. Lubricant Dye

S2.1 The lubricant shall have a color that contrasts with the zinc coating so its presence is visually obvious.
# APPENDIX

(Nonmandatory Information)

## X1. INTENDED APPLICATION

X1.1 Table X1.1 gives additional information for the intended application of nuts.

### TABLE X1.1 Nut and Bolt Suitability Guide

<table>
<thead>
<tr>
<th>Grade of Bolt</th>
<th>Surface Finish</th>
<th>Nominal Size, in.</th>
<th>Recommended&lt;sup&gt;a&lt;/sup&gt;</th>
<th>A563 Grade and ANSI Nut Style&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Suitable&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hex</td>
<td>Heavy Hex</td>
<td>Cube</td>
</tr>
<tr>
<td>A 307 Grade A</td>
<td>non-zinc-coated and zinc-coated</td>
<td>¼ to ½</td>
<td>A</td>
<td>A</td>
<td>B,D,DH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;½ to 2</td>
<td>A</td>
<td>A</td>
<td>A&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;½ to 4</td>
<td>A</td>
<td>A</td>
<td>...</td>
</tr>
<tr>
<td>A 307 Grade B</td>
<td>non-zinc-coated and zinc-coated</td>
<td>½ to 1½</td>
<td>A</td>
<td>A</td>
<td>B,D,DH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;½ to 2</td>
<td>A</td>
<td>A</td>
<td>A&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;½ to 4</td>
<td>A</td>
<td>A</td>
<td>...</td>
</tr>
<tr>
<td>A 325 Type 1</td>
<td>non-zinc-coated</td>
<td>½ to 1½</td>
<td>C</td>
<td>...</td>
<td>C,D,DH,DH3</td>
</tr>
<tr>
<td></td>
<td>zinc-coated</td>
<td>½ to 1½</td>
<td>DH</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>A 325 Type 3</td>
<td>non-zinc-coated</td>
<td>½ to 1½</td>
<td>C</td>
<td>...</td>
<td>D</td>
</tr>
<tr>
<td>A 354 Grade BC</td>
<td>non-zinc-coated</td>
<td>¼ to 1½</td>
<td>C</td>
<td>...</td>
<td>C,D,DH,DH3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;½ to 4</td>
<td>C</td>
<td>...</td>
<td>C,D,DH,DH3</td>
</tr>
<tr>
<td>A 354 Grade BD</td>
<td>non-zinc-coated</td>
<td>¼ to 1½</td>
<td>DH</td>
<td>...</td>
<td>DH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;½ to 4</td>
<td>DH</td>
<td>...</td>
<td>DH</td>
</tr>
<tr>
<td>A 394 Type 1</td>
<td>non-zinc-coated</td>
<td>½ to 1</td>
<td>A</td>
<td>...</td>
<td>B,D</td>
</tr>
<tr>
<td>A 394 Type 2</td>
<td>zinc-coated</td>
<td>½ to 1</td>
<td>DH</td>
<td>...</td>
<td>D</td>
</tr>
<tr>
<td>A 394 Type 3</td>
<td>non-zinc-coated</td>
<td>½ to 1</td>
<td>DH3</td>
<td>...</td>
<td>C3</td>
</tr>
<tr>
<td>A 449 Types 1 and 2</td>
<td>non-zinc-coated</td>
<td>¼ to 1½</td>
<td>B</td>
<td>...</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;½ to 3</td>
<td>A</td>
<td>...</td>
<td>C,D,DH,DH3</td>
</tr>
<tr>
<td>A 490 Types 1 and 2</td>
<td>non-zinc-coated</td>
<td>½ to 1½</td>
<td>DH</td>
<td>...</td>
<td>DH</td>
</tr>
<tr>
<td>A 490 Type 3</td>
<td>non-zinc-coated</td>
<td>½ to 1½</td>
<td>DH3</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>A 587 zinc-coated</td>
<td>¼ to 3</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

---

<sup>a</sup> The availability of DH nuts in nominal sizes ¼ in. and larger is very limited and generally available only on special orders for 50,000 pieces or more. For smaller quantities A194 Gr. 2H nuts should be considered.

<sup>b</sup> "Recommended" denotes a commercially available nut having the most suitable mechanical properties and dimensional configuration (style) that will make it possible to torque the bolt to the required load when used in combination with the nut.

<sup>c</sup> "Suitable" denotes nuts having mechanical properties that will make it possible to torque the bolt to the required load when used in combination with the nut; but, which require consideration of dimensional configuration (style) suitability and availability. Others are not suitable.

<sup>a</sup> The term "bolt" includes all externally threaded types of fasteners.

<sup>2</sup> Non-zinc-coated nuts are not intended for use with externally threaded fasteners which have a plain (nonplated or noncoated) finish or have a plating or coating of insufficient thickness to necessitate overlapping the nut thread to provide assembly. Zinc-coated nuts are intended for use with externally threaded fasteners which are hot-dip zinc-coated, mechanically zinc-coated, or have a plating or coating of sufficient thickness to necessitate overlapping the nut thread to provide assembly.

<sup>f</sup> Hex nuts in nominal sizes over 1½ to 2 in. inclusive are not covered in the tables of tabulated sizes in ANSI B18.2.2 but are commercially available. Such nuts are suitable. See 7.2 for dimensions.
SUMMARY OF CHANGES

Committee F16 has identified the location of selected changes made to this standard since the last issue, A 563–00, that may impact the use of this standard. (Approved Jan. 1, 2004.)

(1) Added Section 1.4 that references Terminology F 1789 for definitions of terms.
Standard Specification for Carbon and Alloy Steel Nuts [Metric]

1. Scope

1.1 This specification covers chemical and mechanical requirements for eight property classes of hex and hex-flange carbon and alloy steel nuts for general structural and mechanical uses on bolts, studs, and other externally threaded parts.

Note 1—Throughout this specification, the term class means property class.

Note 2—Requirements for the four classes 5, 9, 10, and 12 are essentially identical with requirements given for these classes in ISO 898/II. Requirements for Classes 8S and 10S are essentially identical with requirements in an ISO 4775 Hexagon Nuts for High-Strength Structural Bolting with Large Width Across Flats, Product Grade B, Property Classes 8 and 10. Classes 8S3 and 10S3 are not recognized in ISO standards.

1.2 Classes 8S3 and 10S3 nuts have atmospheric corrosion resistance and weathering characteristics comparable to those of the steels covered in Specification A 588/A 588M. The atmospheric corrosion resistance of these steels is substantially better than that of carbon steel with or without copper addition (see 5.2). When properly exposed to the atmosphere, these steels can be used bare (uncoated) for many applications.

1.3 The nut size range for which each class is applicable is given in the table on mechanical requirements.

1.4 Appendix X1 gives guidance to assist designers and purchasers in the selection of a suitable class.

1.5 Appendix X2 gives data on the properties of slotted hex nuts and hex jam nuts.

Note 3—This specification is the metric companion of Specification A 563.

1.6 Terms used in this specification are defined in Specification F 1789 unless otherwise defined herein.

2. Referenced Documents

2.1 ASTM Standards:
A 153/A 153M Specification for Zinc Coating (Hot-Dip) on
Iron and Steel Hardware
A 325M Specification for Structural Bolts, Steel Heat Treated 830 MPa Minimum Tensile Strength [Metric]
A 394 Specification for Steel Transmission Tower Bolts, Zinc-Coated and Bare
A 490M Specification for High-Strength Steel Bolts, Classes 10.9 and 10.9.3, for Structural Steel Joints [Metric]
A 588/A 588M Specification for High-Strength Low-Alloy Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4 in. [100 mm] Thick
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
D 3951 Practice for Commercial Packaging
F 568M Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners
F 606M Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets [Metric]
F 812/F 812M Specification for Surface Discontinuities of Nuts, Inch and Metric Series
F 1789 Terminology for F16 Mechanical Fasteners

2.2 ANSI Standards:
B 1.13M Metric Screw Threads—M Profile
B 18.2.4.1M Metric Hex Nuts, Style 1
B 18.2.4.2M Metric Hex Nuts, Style 2
B 18.2.4.3M Metric Slotted Hex Nuts
B 18.2.4.4M Metric Hex Flange Nuts

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1 This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.02 on Steel Bolts, Nuts, Rivets, and Washers.


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3. Ordering Information

3.1 Orders for nuts under this specification shall include the following:

3.1.1 Quantity (number of nuts);
3.1.2 Nominal diameter and thread pitch;
3.1.3 Dimensional style of nut (for example, hex, heavy hex, or hex flange);
3.1.4 Property class of nut;
3.1.5 Zinc Coating—Specify the zinc coating process required, hot-dip, mechanically deposited, or no preference (see 4.7);
3.1.6 Other Finishes—Specify other protective finish if required;
3.1.7 ASTM designation and year of issue; and
3.1.8 Any special requirements.

3.2 The strength requirements for any class of nut may be satisfied by substituting a nut of a higher class provided that the nut width across flats is the same. With the written approval of the purchaser, the supplier may substitute as follows: Class 12 nuts for Class 8S; and Class 9 nuts for Class 5; Class 10S for Class 8S; Class 8S3 nuts for Classes 10, 9, and 5; Class 10 nuts for Classes 9 and 5. The supplier shall specify the zinc coating process, for example, hot-dip, mechanically deposited, or no preference.

3.3 When order is placed for nuts made of steel having a manganese content of 1.35 % min. to 1.75 % max., the purchaser, the supplier may substitute as follows: Class 12 nuts for Class 8S; and Class 9 nuts for Class 5; Class 10S for Class 8S; Class 8S3 nuts for Classes 10, 9, and 5; Class 10 nuts for Classes 9 and 5. The supplier shall specify the zinc coating process, for example, hot-dip, mechanically deposited, or no preference.

3.4 The purchaser approval.

3.5 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification A 153/A 153M, Class C, or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. All components of mating fasteners (bolts, nuts, and washers) shall be coated by the same zinc coating process and the supplier’s option is limited to one process per item with no mixed processes in a lot.

3.6 Hot-dip zinc coated nuts shall be tapped after zinc coating in accordance with the thread limits in 7.8.

3.7 Mechanically deposited zinc-coated nuts for assembly with mechanically deposited zinc-coated bolts shall be tapped oversize in accordance with the thread limits in 7.8 prior to zinc coating and need not be retapped afterwards.

3.8 Hot-dip and mechanically deposited zinc-coated Class 10S nuts shall be provided with an additional lubricant that shall be clean and dry to the touch.

4. Materials and Manufacture

4.1 Steel for nuts shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

4.2 Nuts may be made cold or hot by forming, pressing, or punching, or may be machined from bar stock.

4.3 Classes 10, 12, 10S, and 10S3 nuts shall be heat treated by quenching in a liquid medium from a temperature above the transformation temperature and tempering at a temperature of at least 425°C.

4.4 Classes 8S and 8S3 nuts made of any steel permitted for these classes may be heat treated by quenching in a liquid medium from a temperature above the transformation temperature and tempering at a temperature of at least 425°C.

4.5 Class 8S nuts made of steel having a carbon content not exceeding 0.20 %, phosphorus not exceeding 0.04 %, and sulfur not exceeding 0.05 % by heat analysis may be heat treated by quenching in a liquid medium from a temperature above the transformation temperature and need not be tempered. When this heat treatment is used, particular attention shall be paid to the requirements in 6.1.

4.6 Threads shall be formed, tapped, or machined.

4.7 Zinc Coatings, Hot-Dip and Mechanically Deposited:

4.7.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc coating process, for example, hot-dip, mechanically deposited, or no preference.

4.7.2 When hot-dip is specified, the fasteners shall be zinc-coated by the hot-dip process in accordance with the requirements of Class C of Specification A 153/A 153M.

4.7.3 When mechanically deposited is specified, the fasteners shall be zinc-coated by the mechanical-deposition process in accordance with the requirements of Class 50 of Specification B 695.

4.7.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification A 153/A 153M, Class C, or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. All components of mating fasteners (bolts, nuts, and washers) shall be coated by the same zinc coating process and the supplier’s option is limited to one process per item with no mixed processes in a lot.

4.7.5 Hot-dip zinc coated nuts shall be tapped after zinc coating in accordance with the thread limits in 7.8.

4.7.6 Mechanically deposited zinc-coated nuts for assembly with mechanically deposited zinc-coated bolts shall be tapped oversize in accordance with the thread limits in 7.8 prior to zinc coating and need not be retapped afterwards.

5. Chemical Composition

5.1 Classes 5, 9, 8S, 10, 10S, and 12 shall conform to the chemical composition specified in Table 1.

5.2 Classes 8S3 and 10S3 shall conform to the chemical composition specified in Table 2. See Guide G 101 for methods of estimating corrosion resistance of low alloy steels.

### Table 1: Chemical Requirements

<table>
<thead>
<tr>
<th>Property Class of Nut</th>
<th>Composition, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Analysis</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>5, 9, 8S</td>
<td>heat product</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>100, 10S</td>
<td>heat product</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>heat product</td>
</tr>
<tr>
<td>8S3, 10S3</td>
<td>See Table 2</td>
</tr>
</tbody>
</table>

A For Classes 5 and 9, a sulfur content of 0.23 % max. is acceptable with the purchasers approval.

B For Classes 10 and 12, a sulfur content of 0.15 % max. is acceptable provided the manganese is 1.35 % min.
5.3 Resulfurized or rephosphorized steel, or both, are not subject to rejection based on product analysis for sulfur or phosphorus unless misapplication is clearly indicated.

5.4 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for Classes 10, 12, 10S, and 10S3.

5.5 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 The hardness of nuts of each class shall not exceed the maximum hardness specified for the class in Table 3. This shall be the only hardness requirement for nuts that are proof load tested.

6.2 Unless proof load testing is specified in the inquiry and purchase order, nuts of all classes in nominal thread diameters M4 and smaller, and nuts of all classes with proof loads greater than 530 kN, as specified in Table 4, may be furnished on the basis of having a hardness not less than the minimum hardness specified in Table 3.

6.3 Nuts of all classes, except those covered in 6.2, shall withstand the proof load stress specified for the diameter and class of nut in Table 3.

**Note**: The proof load of a nut is the axially applied load the nut must withstand without thread stripping or rupture. Proof loads (Table 4) are computed by multiplying proof load stress (Table 3) by the nut thread stress area.

7. Dimensions

7.1 Unless otherwise specified, nuts shall be furnished plain (non-coated nor plated).

7.2 Class 5 nuts in nominal thread diameters M36 and smaller shall conform to dimensions for hex nuts, Style 1, given in ANSI B 18.2.4.1M. Class 5 nuts in nominal thread

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**TABLE 2 Chemical Requirements for Classes 8S3 and 10S3 Nuts**

<table>
<thead>
<tr>
<th>Element</th>
<th>Composition, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Carbon:</td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.33–0.40</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.31–0.42</td>
</tr>
<tr>
<td>Manganese:</td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.90–1.20</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.86–1.24</td>
</tr>
<tr>
<td>Phosphorus:</td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.07–0.15</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.07–0.155</td>
</tr>
<tr>
<td>Sulfur:</td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.050 max</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.055 max</td>
</tr>
<tr>
<td>Silicon:</td>
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<tr>
<td>Heat analysis</td>
<td>0.20–0.90</td>
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<tr>
<td>Product analysis</td>
<td>0.15–0.95</td>
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<td>Copper:</td>
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<td>Heat analysis</td>
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<td>Product analysis</td>
<td>0.22–0.58</td>
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<tr>
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<tr>
<td>Heat analysis</td>
<td>1.00 max</td>
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<tr>
<td>Product analysis</td>
<td>1.03 max</td>
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<td>Chromium:</td>
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<tr>
<td>Heat analysis</td>
<td>0.30–1.25</td>
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<tr>
<td>Product analysis</td>
<td>0.25–1.30</td>
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<tr>
<td>Vanadium:</td>
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</tr>
<tr>
<td>Heat analysis</td>
<td>0.020 min</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.010 min</td>
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<tr>
<td>Molybdenum:</td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.06 max</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.07 max</td>
</tr>
<tr>
<td>Titanium:</td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.05 max</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.05 max</td>
</tr>
</tbody>
</table>

*Class 8S3 nuts may be made of any of the listed steel analyses. Selection of steel analysis shall be the option of the manufacturer.

*Nickel or molybdenum may be used.*

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diameters M42 and larger shall conform to dimensions for heavy hex nuts given in ANSI B 18.2.4.6M.

7.3 Class 9 nuts in nominal thread diameters M20 and smaller shall conform to dimensions for hex nuts, Style 2, given in ANSI B 18.2.4.2M or for hex flange nuts given in ANSI B 18.2.4.4M. When the dimensional style of nut is not designated by the purchaser, hex nuts, Style 2, in conformance with ANSI B 18.2.4.2M shall be furnished. Class 9 nuts in nominal thread diameters M24 to M36 inclusive shall conform to dimensions for hex nuts, Style 2 given in ANSI B 18.2.4.2M. Class 9 nuts in nominal thread diameters M42 and larger shall conform to dimensions for heavy hex nuts given in ANSI B 18.2.4.6M.

7.4 Class 10 nuts in nominal thread diameters M20 and smaller shall conform to dimensions for hex nuts, Style 1, given in ANSI B 18.2.4.1M or for hex flange nuts given in ANSI B 18.2.4.4M. When the dimensional style of nut is not designated by the purchaser, hex nuts, Style 1, in conformance with ANSI B 18.2.4.1M shall be furnished. Class 12 nuts in nominal thread diameters M24 to M36 inclusive shall conform to dimensions for hex nuts, Style 2, given in ANSI B 18.2.4.2M. Class 12 nuts in nominal thread diameters M42 and larger shall conform to dimensions for heavy hex nuts given in ANSI B 18.2.4.6M.

7.5 Class 12 nuts in nominal thread diameters M20 and smaller shall conform to dimensions for hex nuts, Style 2, given in ANSI B 18.2.4.2M or for hex flange nuts given in ANSI B 18.2.4.4M. When the dimensional style of nut is not designated by the purchaser, hex nuts, Style 2, in conformance with ANSI B 18.2.4.2M shall be furnished. Class 12 nuts in nominal thread diameters M42 and larger shall conform to dimensions for heavy hex nuts given in ANSI B 18.2.4.6M. When the dimensional style of the nut is not designated by the purchaser, hex nuts, Style 2, in conformance with ANSI B 18.2.4.2M shall be furnished. Class 12 nuts in nominal thread diameters M24 to M36 inclusive shall conform to dimensions for hex nuts, Style 2, given in ANSI B 18.2.4.2M. Class 12 nuts in nominal thread diameters M42 and larger shall conform to dimensions for heavy hex nuts given in ANSI B 18.2.4.6M.

7.6 Classes 8S, 8S3, 10S, and 10S3 in nominal thread diameters M12 to M36 inclusive shall conform to dimensions for heavy hex nuts given in ANSI B 18.2.4.6M.

7.7 Unless otherwise specified, threads in nuts shall be the metric coarse thread series as specified in ANSI B 1.13M, and shall have grade 6H tolerances.

7.8 This requirement applies to nuts hot-dip and mechanically zinc-coated that are to be used on bolts, screws, or studs that have metric coarse threads with Grade 6G tolerances before zinc-coating and then are hot-dip or mechanically zinc-coated, except as noted in 7.9, in accordance with 4.7.2 and 4.7.3. Such nuts shall be tapped oversize to have internal threads with maximum and minimum limits that exceed the maximum and minimum limits specified for metric coarse internal threads with Grade 6H tolerances by the following diametral allowances:

### TABLE 3 Mechanical Requirements of Nuts

<table>
<thead>
<tr>
<th>Nominal Diameter</th>
<th>Property Class</th>
<th>Proof Load Stress, MPa</th>
<th>Hardness</th>
<th>Proof Load Stress, MPa</th>
<th>Hardness</th>
<th>Proof Load Stress, MPa</th>
<th>Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1.6 to M2.5</td>
<td>5</td>
<td>520</td>
<td>B70</td>
<td>C30</td>
<td>130</td>
<td>302</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>5 (over-tapped)</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>M3 to M4</td>
<td>5</td>
<td>580</td>
<td>B70</td>
<td>C30</td>
<td>130</td>
<td>302</td>
<td>465</td>
</tr>
<tr>
<td></td>
<td>5 (over-tapped)</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>M5 and M6</td>
<td>5</td>
<td>590</td>
<td>B70</td>
<td>C30</td>
<td>130</td>
<td>302</td>
<td>470</td>
</tr>
<tr>
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<td>5 (over-tapped)</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
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<td>...</td>
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<tr>
<td>M8 and M10</td>
<td>5</td>
<td>610</td>
<td>B70</td>
<td>C30</td>
<td>130</td>
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<td>490</td>
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<td></td>
<td>5 (over-tapped)</td>
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<tr>
<td>M12 to M16</td>
<td>5</td>
<td>630</td>
<td>B70</td>
<td>C30</td>
<td>130</td>
<td>302</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>5 (over-tapped)</td>
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<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>M20 to M36</td>
<td>5</td>
<td>630</td>
<td>B70</td>
<td>C30</td>
<td>130</td>
<td>302</td>
<td>500</td>
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<td></td>
<td>5 (over-tapped)</td>
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<td>...</td>
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<tr>
<td>M42 to M100</td>
<td>5</td>
<td>630</td>
<td>B70</td>
<td>C30</td>
<td>128</td>
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<td>500</td>
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<tr>
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<td>5 (over-tapped)</td>
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<td>...</td>
<td>...</td>
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<td>...</td>
</tr>
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### TABLE 4 Mechanical Requirements of Nuts

<table>
<thead>
<tr>
<th>Nominal Diameter</th>
<th>Property Class</th>
<th>Proof Load Stress, MPa</th>
<th>Hardness</th>
<th>Proof Load Stress, MPa</th>
<th>Hardness</th>
<th>Proof Load Stress, MPa</th>
<th>Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1.6 to M2.5</td>
<td>10</td>
<td>1040</td>
<td>C26</td>
<td>C36</td>
<td>272</td>
<td>353</td>
<td>1150</td>
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<td></td>
<td>12</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
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<tr>
<td>M3 to M4</td>
<td>10</td>
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<td>C26</td>
<td>C36</td>
<td>272</td>
<td>353</td>
<td>1150</td>
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<td>12</td>
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<td>M5 and M6</td>
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<td>C36</td>
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<td>M12 to M16</td>
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<td>C26</td>
<td>C36</td>
<td>272</td>
<td>353</td>
<td>1200</td>
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<td>M20 to M36</td>
<td>10</td>
<td>1060</td>
<td>C26</td>
<td>C36</td>
<td>272</td>
<td>353</td>
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<td>M42 to M100</td>
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<td>353</td>
<td>1200</td>
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</tbody>
</table>

### TABLE 5 Mechanical Requirements of Nuts

<table>
<thead>
<tr>
<th>Nominal Diameter</th>
<th>Property Class</th>
<th>Proof Load Stress, MPa</th>
<th>Hardness</th>
<th>Proof Load Stress, MPa</th>
<th>Hardness</th>
<th>Proof Load Stress, MPa</th>
<th>Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1.6 to M2.5</td>
<td>8S and 8S3</td>
<td>1075</td>
<td>B99</td>
<td>C38</td>
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<td>10S and 10S3</td>
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<td>M3 to M4</td>
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<td>M5 and M6</td>
<td>8S and 8S3</td>
<td>...</td>
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<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>10S and 10S3</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>M8 and M10</td>
<td>8S and 8S3</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>10S and 10S3</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>M12 to M16</td>
<td>8S and 8S3</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>10S and 10S3</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>M20 to M36</td>
<td>8S and 8S3</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>10S and 10S3</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>M42 to M100</td>
<td>8S and 8S3</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>10S and 10S3</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Nut Diameter

Diametral Allowance, µm

M5  156
M6  200
M8  255
M10 310
M12 365
M14 and M16 420
M20 and M22 530
M24 and M27 640
M30 750
M36 860
M42 970
M48 1080
M56 1190
M64 to M100 1300

TABLE 4 Nut Proof Load Values, kN

NOTE 1—Nuts of diameters and classes where no proof loads are given are non-standard.

NOTE 2—Proof loads are computed by multiplying proof load stress (Table 3) by thread stress area and dividing by 1000.

<table>
<thead>
<tr>
<th>Nominal Diameter and Thread Pitch</th>
<th>Thread Stress Area, mm²</th>
<th>Property Class of Nut</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5 (over-tapped)</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>M1.6 x 0.35</td>
<td>1.27</td>
<td>0.66</td>
</tr>
<tr>
<td>M2 x 0.4</td>
<td>2.07</td>
<td>1.08</td>
</tr>
<tr>
<td>M2.5 x 0.45</td>
<td>3.39</td>
<td>1.76</td>
</tr>
<tr>
<td>M3 x 0.5</td>
<td>5.03</td>
<td>2.62</td>
</tr>
<tr>
<td>M3.5 x 0.6</td>
<td>6.78</td>
<td>3.53</td>
</tr>
<tr>
<td>M4 x 0.7</td>
<td>8.78</td>
<td>4.57</td>
</tr>
<tr>
<td>M5 x 0.8</td>
<td>14.2</td>
<td>8.23</td>
</tr>
<tr>
<td>M6 x 1</td>
<td>20.1</td>
<td>11.7</td>
</tr>
<tr>
<td>M8 x 1.25</td>
<td>36.6</td>
<td>21.6</td>
</tr>
<tr>
<td>M10 x 1.5</td>
<td>58.0</td>
<td>34.2</td>
</tr>
<tr>
<td>M12 x 1.75</td>
<td>84.3</td>
<td>51.4</td>
</tr>
<tr>
<td>M14 x 2</td>
<td>115</td>
<td>70.2</td>
</tr>
<tr>
<td>M16 x 2</td>
<td>157</td>
<td>95.8</td>
</tr>
<tr>
<td>M20 x 2.5</td>
<td>245</td>
<td>154</td>
</tr>
<tr>
<td>M22 x 2.5</td>
<td>303</td>
<td>...</td>
</tr>
<tr>
<td>M24 x 3</td>
<td>353</td>
<td>222</td>
</tr>
<tr>
<td>M27 x 3</td>
<td>459</td>
<td>...</td>
</tr>
<tr>
<td>M30 x 3.5</td>
<td>561</td>
<td>353</td>
</tr>
<tr>
<td>M36 x 4</td>
<td>817</td>
<td>515</td>
</tr>
<tr>
<td>M42 x 4.5</td>
<td>1120</td>
<td>706</td>
</tr>
<tr>
<td>M48 x 5</td>
<td>1470</td>
<td>920</td>
</tr>
<tr>
<td>M56 x 5.5</td>
<td>2030</td>
<td>1280</td>
</tr>
<tr>
<td>M64 x 6</td>
<td>2680</td>
<td>1690</td>
</tr>
<tr>
<td>M72 x 6</td>
<td>3460</td>
<td>2180</td>
</tr>
<tr>
<td>M80 x 6</td>
<td>4340</td>
<td>2730</td>
</tr>
<tr>
<td>M90 x 6</td>
<td>5590</td>
<td>3520</td>
</tr>
<tr>
<td>M100 x 6</td>
<td>6990</td>
<td>4400</td>
</tr>
</tbody>
</table>

NOTE 8—Bolts, screws, and studs in diameters smaller than M10 are not normally hot-dip zinc-coated.

7.8.1 Internal threads shall be subject to acceptance gaging using GO and HI thread plug gages having size limits as established in 7.8. Threads of nuts tapped after zinc coating (4.7) shall meet GO and HI thread plug gaging requirements as tapped. Threads of nuts tapped prior to zinc coating (4.8) shall meet HI thread plug gaging requirements prior to zinc coating and GO thread plug gaging requirements after zinc coating.

7.9 Nuts to be used on bolts, screws, or studs that are hot-dip or mechanically zinc-coated to requirements other than specified in 7.8 shall be tapped oversize by a diametral allowance sufficient to permit assembly on the coated externally threaded fastener.

NOTE 9—If the over-tapping diametral allowance is greater than the limit specified in 7.8, the purchaser is cautioned that the nut may not meet the proof load stress specified in Table 3.

7.10 When specifically permitted by the purchaser, nuts for bolts, screws, or studs having an electrodeposited coating, such as cadmium, zinc, etc., or having a chemically applied coating may be tapped oversize by a diametral allowance sufficient to permit assembly on the coated externally threaded fastener.

NOTE 10—If the overtapping diametral allowance is greater than the limit specified in 7.8, the purchaser is cautioned that the nut may not meet the proof load stress specified in Table 3.

8. Workmanship

8.1 Surface discontinuity limits shall be in accordance with Specification F 812/F 812M.

9. Number of Tests

9.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product
conforms to the specified requirements (Section 15). Additional tests of individual shipments of material are not ordinarily contemplated. Individual heats of steel are not identified in the finished product.

9.2 When additional tests are specified in the inquiry and purchase order, a lot, for purposes of selecting test samples, shall consist of all nuts offered for inspection at one time that have the following common characteristics:

9.2.1 Property class,
9.2.2 Nominal diameter,
9.2.3 Style,
9.2.4 Thread series and tolerance grade, and
9.2.5 Surface finish.

9.3 Unless otherwise specified in the inquiry and purchase order, the number of tests for each lot of each required property shall be as follows:

<table>
<thead>
<tr>
<th>Number of Nuts in Lot</th>
<th>Number of Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and under</td>
<td>1</td>
</tr>
<tr>
<td>801 to 8000</td>
<td>2</td>
</tr>
<tr>
<td>8001 to 22 000</td>
<td>3</td>
</tr>
<tr>
<td>Over 22 000</td>
<td>5</td>
</tr>
</tbody>
</table>

10. Test Methods

10.1 Hardness and proof load tests of nuts shall be performed in accordance with requirements of Test Method F 606M.

10.2 For nut proof load testing, the speed of testing as determined with a free-running cross head shall be a maximum of 25 mm/min.

11. Report

11.1 When specified in the order, the manufacturer shall furnish a test report certified to be the last completed set of mechanical tests for each stock size in each shipment.

12. Inspection

12.1 If the inspection described in 12.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

12.2 The inspector representing the purchaser shall have free entry to all parts of manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection required by the specification that are requested by the purchaser’s representative shall be made prior to shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

13. Product Marking

13.1 Nuts in nominal thread diameters M4 and smaller need not be marked.

13.2 Nuts of all classes, in nominal thread diameters M5 and larger, shall be marked with the property class designation (5, 9, 10, 12, 8S, 10S, 8S3, or 10S3) on the top or bearing surface, on the top of flange, or on one of the wrenching flats of the nut. Markings located on the top or bearing surface or on the top of the flange shall be positioned with the base of the numeral(s) oriented toward the nut periphery. Class 9 nuts marked on one of the wrenching flats shall have the numeral 9 underlined.

13.3 Additionally, nuts of Classes 10, 12, 8S, 8S3, 10S, and 10S3 shall be marked with a symbol to identify the manufacturer or private label distributor, as appropriate. The manufacturer’s identification symbol shall be of his design.

13.4 For Classes 8S3 and 10S3 nuts, the manufacturer may add other distinguishing marks to indicate the nut is atmospheric corrosion resistant and of a weathering grade of steel.

13.5 Markings may be raised or depressed at the option of the manufacturer. However, if markings are located on the bearing surface or on one of the wrenching flats, they shall be depressed.

13.6 Property class and manufacturer’s or private label distributor’s identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

14. Packaging and Package Marking

14.1 Packaging:

14.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

14.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

14.2 Package Marking:

14.2.1 Each shipping unit shall include or be plainly marked with the following information:

14.2.1.1 ASTM designation and grade,
14.2.1.2 Size,
14.2.1.3 Name and brand or trademark of the manufacturer,
14.2.1.4 Number of pieces,
14.2.1.5 Purchase order number, and
14.2.1.6 Country of origin.

15. Responsibility

15.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

16. Keywords

16.1 alloy steel; carbon steel; metric; nuts; steel; weathering steel
X1. INTENDED APPLICATION

X1.1 Table X1.1 presents guidance on the strength suitability of nuts for use in combination with various property classes of metric bolts, screws and studs.

X1.2 Various nut styles (H1, H2, HH, and HF) have different dimensions (width across flats, thickness, flange diameter). Purchasers are cautioned to consider the dimensional requirements of the application when selecting the most appropriate nut.

### TABLE X1.1 Nut/Bolt Suitability Guide

<table>
<thead>
<tr>
<th>Class of Bolt, Screw, or Stud</th>
<th>Nominal Diameter of Bolt/Nut Combination</th>
<th>Surface Finish of Bolt</th>
<th>Property Class and Dimensional Style of Nut</th>
</tr>
</thead>
<tbody>
<tr>
<td>F 568, Class 4.6</td>
<td>M5 to M36</td>
<td>plain</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td></td>
<td>M42 to M100</td>
<td>zinc-coated</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td>F 568, Class 4.8</td>
<td>M1.6 to M16</td>
<td>plain</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td></td>
<td>M42 to M100</td>
<td>zinc-coated</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td>F 568, Class 5.8</td>
<td>M5 to M24</td>
<td>plain</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td></td>
<td>M16 to M36</td>
<td>plain</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td></td>
<td>M42 to M100</td>
<td>zinc-coated</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td>F 568, Class 8.8</td>
<td>M16 to M36</td>
<td>plain</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td></td>
<td>M42 to M100</td>
<td>zinc-coated</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td>F 568, Class 8.8.3</td>
<td>M16 to M36</td>
<td>plain</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td></td>
<td>M42 to M100</td>
<td>zinc-coated</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td>F 568, Class 9.8</td>
<td>M1.6 to M16</td>
<td>plain</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td></td>
<td>M42 to M100</td>
<td>zinc-coated</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td>F 568, Class 10.9</td>
<td>M5 to M36</td>
<td>plain</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td></td>
<td>M42 to M100</td>
<td>zinc-coated</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td>F 568, Class 10.9.3</td>
<td>M16 to M36</td>
<td>plain</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td></td>
<td>M42 to M100</td>
<td>zinc-coated</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td>A 325M, Types 1 and 2</td>
<td>M16 to M36</td>
<td>plain</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td></td>
<td>M42 to M100</td>
<td>zinc-coated</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td>A 325M, Type 3</td>
<td>M16 to M36</td>
<td>plain</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
<tr>
<td></td>
<td>M42 to M100</td>
<td>zinc-coated</td>
<td>$H_1$, $H_2$, $H_3$, $H_4$</td>
</tr>
</tbody>
</table>

### Notes

- "Bolt" includes all types of externally threaded products.
- "Plain" applies to any bolt that is non-coated or non-plated, or that has a coating or plating of insufficient thickness to require that the nut be overtapped. "Zinc-coated" applies to any bolt that is hot-dip or mechanically zinc-coated or otherwise coated or plated with a coating or plating of sufficient thickness to require the use of overtapped nuts.
- Recommended nut class and style.
- Non-suitable nut.
X2. SLOTTED HEX NUTS AND HEX JAM NUTS

X2.1 Slotted Hex Nuts:

X2.1.1 Slotted hex nuts are available in nominal thread diameters M5 to M36 inclusive, and in Property Classes 5 and 10.

X2.1.2 Class 5 nuts are made of carbon steel conforming to chemical composition requirements given in Table 1. Class 10 nuts are made of carbon or alloy steel conforming to chemical composition requirements given in Table 1, and are heat treated as specified in 4.3.

X2.1.3 Classes 5 and 10 nuts have hardnesses as specified in Table 3, and proof load stresses equal to 80 % of the values specified in Table 3 for Classes 5 and 10, respectively. Slotted hex nuts are not normally proof load tested.

X2.1.4 Slotted hex nuts conform to dimensions given in ANSI B 18.2.4.3M.

X2.2 Hex Jam Nuts:

X2.2.1 Hex jam nuts are available in nominal thread diameters M5 to M36 inclusive, and in Property Classes 04 and 05.

X2.2.2 Class 04 nuts are made of carbon steel conforming to the chemical composition requirements specified for Class 9 nuts in Table 1. Class 05 nuts are made of carbon or alloy steel conforming to the chemical composition requirements specified for Class 10 nuts in Table 1, and are heat treated as specified in 4.3.

X2.2.3 Class 04 nuts have a proof load stress of 380 MPa, and a hardness of HV 188/302 for all diameters. Class 05 nuts have a proof load stress of 500 MPa, and a hardness of HV 272/353 for all diameters. Hex jam nuts are not normally proof load tested.

X2.2.4 Hex jam nuts conform to dimensions given in ANSI B 18.2.4.5M.

SUMMARY OF CHANGES

This section identifies the location of selected changes to this standard that have been incorporated since the A 563-01 issue. For the convenience of the user, Committee F16 has highlighted those changes that impact the use of this standard. This section may also include descriptions of the changes or reasons for the changes, or both.

(1) Added Section 1.6 that references Terminology F 1789 for definitions of terms.

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8
Standard Specification for
Alloy Steel Socket-Head Cap Screws

This specification covers the requirements for quenched and tempered alloy steel hexagon socket-head cap screws, 0.060 through 4 in. in diameter where high strength is required.

NOTE 1—A complete metric companion to Specification A 574 has been developed—A 574M; therefore no metric equivalents are presented in this specification.

1. Scope

1.1 This specification covers the requirements for quenched and tempered alloy steel hexagon socket-head cap screws, 0.060 through 4 in. in diameter where high strength is required.

2. Referenced Documents

2.1 ASTM Standards:
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
D 3951 Practice for Commercial Packaging
E 3 Methods of Preparation of Metallographic Specimens
E 112 Test Methods for Determining the Average Grain Size
E 384 Test Method for Microhardness of Materials
F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
F 788/F 788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series

2.2 ANSI/ASME Standards:
B1.1 Unified Screw Threads
B18.3 Socket Cap, Shoulder, and Set Screws
B18.24.1 Part Identifying Number (PIN) Code System

2.3 Federal Standard:
H-28 Handbook of Thread Dimensions

3. Terminology

3.1 Definitions:
3.1.1 Definitions of discontinuities covered by 10.2 follow:
3.1.2 crack—a clean crystalline break passing through the grain or grain boundary without inclusion of foreign elements.
3.1.3 inclusions—particles of nonmetallic impurities, usually oxides, sulfides, silicates, and such, which are mechanically held in the steel during solidification.
3.1.4 nicks or pits—depressions or indentations in the surface of the metal.
3.1.5 seam or lap—a noncrystalline break through the metal which is inherently in the raw material.

4. Ordering Information

4.1 Orders for socket head cap screws under this specification shall include the following:
4.1.1 ASTM designation and year of issue.
4.1.2 Quantities (number of pieces by size).
4.1.3 Size and length.
4.2 Orders for socket head cap screws may include the following optional requirements:
4.2.1 Inspection at point of manufacture.
4.2.2 Coating, if a protective finish other than black oxide (thermal or chemical) is required, it must be specified.
4.2.3 Certified test reports (see 11.2).
4.2.4 Additional testing (see 11.3).
4.2.5 Special packaging (see 16.1.2).
4.2.6 Supplementary requirements (see S1).

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4.2.7 Special requirements.
4.2.8 For establishment of a part identifying system, see ASME B18.24.1.

5. Materials and Manufacture

5.1 The screws shall be fabricated from a steel which has been made by the open-hearth, basic-oxygen, or electric-furnace process.

5.2 The screws shall be fabricated from alloy steel made to a fine grain practice. In the event of controversy over grain size, referee tests on finished screws conducted in accordance with Test Method E 112 shall prevail.

5.3 Unless otherwise specified, the heads of screws through 1.500-in. diameter shall be fabricated by hot or cold forging. Over 1.500-in. diameter, the heads may be fabricated by hot or cold forging or by machining. Sockets may be forged or machined.

5.4 Unless otherwise specified, threads of screws shall be rolled for diameters through 0.625 in. and for screw lengths through 4 in. For diameters and lengths other than this, threads may be rolled, cut, or ground.

5.5 The screws shall be heat treated by oil quenching from above the transformation temperature and then tempering at a temperature not lower than 650°F.

5.6 Standard Finishes—Unless otherwise specified, the screws shall be furnished with one of the following “standard surfaces as manufactured”, at the option of the manufacturer; (1) bright uncoated, (2) thermal black oxide, or (3) chemical black oxide. Hydrogen embrittlement tests shall not be required for screws furnished in these conditions.

5.7 Protective Coatings:

5.7.1 When a protective finish other than as specified in 5.6 is required, it shall be specified on the purchase order with the applicable finish specification.

5.7.2 When protective or decorative coatings are applied to the screws, precautions specified by the coating requirements to minimize embrittlement shall be exercised.

6. Chemical Composition

6.1 The screws shall be alloy steel conforming to the chemical composition specified in Table 1. See Supplementary Requirement S1 when specific chemistry grades are required.

6.2 One or more of the following alloying elements: chromium, nickel, molybdenum, or vanadium shall be present in sufficient quantity to ensure that the specified strength properties are met after oil quenching and tempering. As a guide for selecting material, an alloy steel should be capable of meeting the specified mechanical requirements if the “as oil quenched” core hardness one diameter from the point is equal to or exceeds 25 HRC + (55 × carbon content).

6.3 Product analyses may be made by the purchaser from finished screws representing each lot. The chemical composition, thus determined, shall conform to the requirements prescribed for product analysis in Table 1.

6.4 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

6.5 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

7. Mechanical Properties

7.1 The hardness of finished screws shall be 39 to 45 HRC for 0.500 in. and smaller and 37 to 45 HRC for 0.625 in. and larger. This shall be only the mechanical requirements for screws that are shorter than three times the diameter or that have insufficient threads for tension testing.

7.2 Screws, other than those exempted in 7.1 and 7.3, shall meet the proof load and tensile requirements in Table 2 and Table 3. The screws shall be tension tested with a wedge of the angle specified in Table 4 under the head. To meet the requirements of the wedge test, there must be a tensile failure in the body or thread section. For the purpose of this test, failure means separation into two pieces. Screws threaded to the head shall pass the requirements for this test if the fracture that caused failure originated in the thread area, even though it may have propagated into the fillet area or the head before separation.

7.3 Screws having a diameter larger than 1.500 in. shall be preferably tested in full size and shall meet the requirements of Table 2 and Table 3. When equipment of sufficient capacity is not readily available, screws shall meet 170 ksi, min, tensile strength, 153 ksi, min, yield strength at 0.2 % offset, and 10 % elongation on specimens machined in accordance with Test Methods F 606.

8. Metallurgical Requirement

8.1 Carburization or Decarburization:

8.1.1 There shall be no evidence of carburization or total decarburization on the surfaces of the heat-treated screws when measured in accordance with 12.3.

8.1.2 The depth of partial decarburization shall be limited to the values in Table 5 when measured as shown in Fig. 1 and in accordance with 12.3.

9. Dimensions

9.1 Unless otherwise specified, the product shall conform to the requirements of ANSI B18.3.

9.2 Unless otherwise specified, threads shall be Unified standard: Class 3A, UNRC and UNRF series for screw sizes 0.060 through 1 in. inclusive; Class 2A, UNRC and UNRF series for sizes over 1 in. to 1.500 in. inclusive; and Class 2A UNRC series for sizes larger than 1.500 in. in accordance with ANSI B1.1.

<table>
<thead>
<tr>
<th>TABLE 1 Chemical Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Carbon, min</td>
</tr>
<tr>
<td>Phosphorus, max</td>
</tr>
<tr>
<td>Sulfur, max</td>
</tr>
<tr>
<td>Alloying elements</td>
</tr>
</tbody>
</table>
Illustrated in Fig. 3 to the depths shown in Fig. 2. Permissible and nonpermissible discontinuities are shown in Fig. 2.

**Note 2—**T = actual key engagement.

10.3 **Permissible Head and Body Discontinuities**—Discontinuities as defined above are permitted in the locations illustrated in Fig. 3 to the depths shown in 10.4. These discontinuities are permitted, provided they do not affect the usability and performance of the screw. All discontinuities are to be measured perpendicular to indicated surfaces.

10.4 **Conditions for Permissible Discontinuity Depths:**

10.4.1 **Condition 1**—For bearing area, fillet, and other surfaces, max depth = 0.03D or 0.005 in. (whichever is greater).

**Note 3—**D = nominal diameter of screw.

10.4.2 **Condition 2**—For peripheral discontinuities, max depth = 0.06D, but not to exceed 0.064.

10.5 **Thread Discontinuities**—Threads shall have no laps at the root or on the flanks located below the pitch line. Laps are
permissible at the thread crest to a depth of 25% of the basic thread height and on the thread flanks beyond the pitch diameter. Longitudinal seams in the threads are acceptable within the limits of Condition 1 (10.4.1).

11. Number of Tests and Retests

11.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated. A record of individual heats of steel in each test lot shall be maintained. The container shall be coded to permit identification of the lot.

11.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last complete set of mechanical tests for each stock size in each shipment.

11.3 When additional tests are specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all screws offered for inspection at one time of one diameter and length. From each lot, the number of samples for each requirement shall be as follows:

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and less</td>
<td>1</td>
</tr>
<tr>
<td>Over 800 to 8 000, incl</td>
<td>2</td>
</tr>
<tr>
<td>Over 8 000 to 22 000, incl</td>
<td>3</td>
</tr>
<tr>
<td>Over 22 000</td>
<td>5</td>
</tr>
</tbody>
</table>

11.4 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be retested for the requirement(s) in which it failed. All of the additional samples shall conform to the specification or the lot shall be rejected.

12. Test Methods

12.1 Test the finished screws and specimens, as applicable, for mechanical properties and hardness requirements of Section 7. Testing shall be in accordance with Test Methods F 606 at room temperature. The minimum required length for tension testing shall be 3D. The angle used in wedge tests shall be as specified in Table 4.

12.2 The speed of testing, as determined with a free running crosshead, shall be a maximum of 1 in./min for the tension tests of screws.

12.3 Decarburization and carburization tests shall be conducted as follows:

12.3.1 Section the thread area of the bolt longitudinally through the axis, mount, and polish it in accordance with Methods E 3. Take measurements (1) at the minor diameter in the center of the thread ridge and (2) 0.75 h toward the thread crest on the perpendicular bisector of the thread ridge. Take a measurement (3) on the thread flank approximately at the pitch line at a depth of 0.003 in. Use one of the two methods for carburization/decarburization evaluation either optical or microhardness measurements. The microhardness measurement shall constitute a referee method in case of dispute.

12.3.2 For optical measurement, etch the section in 2 – 4% nitral. Examine the surface of the etched samples under a microscope at 100× using a measuring eyepiece graduated in 0.001-in. increments. The width of any light etching band normally defines the decarburization depth. A dark etching band indicates the possibility of carburization.

12.3.3 Measure microhardness in accordance with Test Method E 384 on unetched specimens using a DPH 136° indenter or a Knoop indenter using the following load application:

<table>
<thead>
<tr>
<th>Number of Threads per Inch</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 40</td>
<td>500 gf</td>
</tr>
<tr>
<td>40, 44, and 48</td>
<td>200 gf</td>
</tr>
<tr>
<td>Over 48</td>
<td>Use optical evaluation in 12.3.2</td>
</tr>
</tbody>
</table>

12.3.3.1 Take measurements at minor diameter (Reading No. 1) on the thread crest bisector to determine base metal hardness. Take measurements (Reading No. 2) on the bisector 0.75 h from the minor measurement toward the thread crest. Also take measurements (Reading No. 3) on the thread flank at the pitch line at a depth within 0.003 from the surface. Reading No. 3 may be taken on the same or an adjacent thread.

12.3.4 Interpret microhardness readings as follows:

12.3.4.1 A decrease of more than 30 hardness points from Reading No. 1 to Reading No. 2 shall be regarded as decarburization and indicates the screw does not conform to specification requirements.

12.3.4.2 An increase of more than 30 hardness points from Reading No. 1 to Reading No. 3 shall be regarded as carburization and indicates that the screw does not conform to specification requirements.

13. Inspection

13.1 If the additional tests described in 11.3 are required by the purchaser it shall be specified in the inquiry, order, or contract.
13.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser’s representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

14. Responsibility

14.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested
and inspected in accordance with this specification and meets all of its requirements.

15. Rejection and Rehearing

15.1 Rejections based on requirements herein shall be reported to the manufacturer within 30 days after receipt of material by the purchaser.

16. Packaging and Package Marking

16.1 Packaging:
16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.
16.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

16.2 Package Marking:
16.2.1 Each shipping unit shall include or be plainly marked with the following information:
16.2.1.1 ASTM designation,
16.2.1.2 Size,
16.2.1.3 Name and brand or trademark of the manufacturer,
16.2.1.4 Number of pieces,
16.2.1.5 Purchase order number, and
16.2.1.6 Country of origin.

17. Keywords

17.1 alloy steel; cap screws; socket head
SUPPLEMENTARY REQUIREMENTS

The following Supplementary Requirement shall apply only when specified by the purchaser in the contract or purchase order. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Specific Grade Chemical Compositions

S1.1 When Supplementary Requirement S1 is specified on the order, the chemical composition shall conform to one of the compositions in Table S1.1 at the option of the supplier, unless a specific composition (Grade) has been specified on the purchase order.

<table>
<thead>
<tr>
<th>Grade Designation</th>
<th>4037</th>
<th>4042</th>
<th>4137</th>
<th>4140</th>
<th>4142</th>
<th>4145</th>
<th>4340</th>
<th>8740</th>
<th>5137M</th>
<th>51B37M</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNS Number</td>
<td>G40370</td>
<td>G40420</td>
<td>G41370</td>
<td>G41400</td>
<td>G41420</td>
<td>G41450</td>
<td>G43400</td>
<td>G87400</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

A Elements shown with an “A” are not applicable to that grade designation.

B Boron is not subject to product analysis.
SUMMARY OF CHANGES

This section identifies the location of changes to this specification that have been incorporated since the -98a issue. Committee F16 has highlighted those changes that affect the technical interpretation or use of this specification.

(1) Added 4.2.8, providing for optional use of ASME B18.24.1, Part Identifying Number (PIN) Code System.

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Designation: A 574M – 00

METRIC

Standard Specification for Alloy Steel Socket-Head Cap Screws [Metric]¹

This standard is issued under the fixed designation A 574M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers the requirements for quenched and tempered alloy steel socket-head cap screws 1.6 mm through 48 mm in diameter having a minimum ultimate tensile strength of 1220 MPa.

Note 1—This specification is the metric companion of Specification A 574.

1.2 The following hazard caveat pertains only to the test method portion, Section 10, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products²
D 3951 Practice for Commercial Packaging³
E 3 Methods of Preparation of Metallographic Specimens⁴
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials⁴
E 112 Test Methods for Determining the Average Grain Size⁴
E 384 Test Method for Microhardness of Materials⁴
F 788/F788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series⁵

2.2 ANSI/ASME Standards:
B18.3.1M Metric Socket Head Cap Screws⁶
B18.24.1 Part Identifying Number (PIN) Code System⁷

3. Ordering Information

3.1 Orders for socket head cap screws under this specification shall include the following information:
3.1.1 Quantity (number of screws),
3.1.2 Dimensions, including nominal thread designation, thread, pitch, and nominal screw length (millimetres),
3.1.3 Name of the screw (SHCS),
3.1.4 ASTM designation and year of issue.

3.2 Orders for socket head cap screws may include the following optional requirements:
3.2.1 Inspection at point of manufacture.
3.2.2 Coating, if required (see 4.6).
3.2.3 Certified Test Reports (see 9.2).
3.2.4 Additional Testing (see 9.3 and 11.1).
3.2.5 Special Packaging (see 14.1.2).
3.2.6 Supplementary Requirement (see S1).
3.2.7 Special Requirements.
3.2.8 For establishment of a part identifying system, see ASME B18.24.1.

4. Materials and Manufacture

4.1 The screws shall be fabricated from steel made to fine grain practice. In the event of controversy over grain size, referee tests on finished screws conducted in accordance with Test Method E 112 shall prevail.

4.2 Screws in sizes up to M20 inclusive, and with lengths up to 10 times the nominal product size or 150 mm, whichever is shorter, shall be cold headed, except that they may be hot headed by agreement of the purchaser. Larger sizes and longer lengths may be cold or hot headed. Screws M42 and larger may be machined. Sockets may be forged or machined at the option of the manufacturer.

¹ This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.02 on Steel Bolts, Nuts, Rivets, and Washers.


² Annual Book of ASTM Standards, Vol 01.03.


⁴ Annual Book of ASTM Standards, Vol 03.01.

⁵ Annual Book of ASTM Standards, Vol 01.08.

⁶ Available from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

⁷ Available from American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016–5990.

*A Summary of Changes section appears at the end of this standard.
4.3 Screws in sizes up to M24 inclusive, and product lengths up to 150 mm inclusive, shall be roll threaded, except by special agreement of the purchaser. Larger products may be rolled, cut, or ground at the option of the manufacturer.

4.4 Socket-head cap screws shall be heat treated by quenching in oil from above the transformation temperature and then tempered by reheating to at least 380°C to within the hardness range specified in Table 1.

4.4.1 The minimum tempering temperature may be verified by submitting screws to 370°C for 30 min at temperature. The mean cross section hardness of three readings on the screw before and after retempering shall not differ by more than 20 DPH.

4.5 Standard Finishes—Unless otherwise specified, the screws shall be furnished with one of the following “standard surfaces as manufactured”, at the option of the manufacturer; (1) bright uncoated, (2) thermal black oxide, or (3) chemical black oxide. Hydrogen embrittlement tests shall not be required for screws furnished in these conditions.

4.6 Protective Coatings:

4.6.1 When a protective finish other than as specified in 4.5 is required, it shall be specified on the purchase order with the applicable finish specification.

4.6.2 When protective or decorative coatings are applied to the screws, precautions specified by the coating requirements to minimize embrittlement shall be exercised.

5. Chemical Composition

5.1 The screws shall be alloy steel conforming to the chemical composition specified in Table 2. See Supplementary Requirement S1 when specific chemistry grades are required.

5.2 One or more of the following alloying elements: chromium, nickel, molybdenum, or vanadium shall be present in the steel in sufficient quantity to ensure the specified strength properties are met after oil quenching and tempering. As a guide for selecting material, an alloy steel should be capable of meeting the specified mechanical requirements if the “as oil quenched” core hardness one diameter from the point is equal to or exceeds 25 HRC + (55 × carbon content).

5.3 Product analyses may be made by the purchaser from finished screws representing each lot. The chemical composition thus determined shall conform to the requirements specified for the product analysis in Table 2.

<table>
<thead>
<tr>
<th>TABLE 2 Chemical Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element</td>
</tr>
<tr>
<td>--------------------------------</td>
</tr>
<tr>
<td>Carbon</td>
</tr>
<tr>
<td>Phosphorus, max</td>
</tr>
<tr>
<td>Sulfur, max</td>
</tr>
<tr>
<td>Alloying elements</td>
</tr>
</tbody>
</table>

5.4 Steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

5.5 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 Socket head cap screws shall be tested in accordance with the mechanical testing requirements specified in Table 3, and shall meet the mechanical requirements in Table 1 and Table 4.

6.2 Screws in sizes 1.6 through 36-mm diameter shall be wedge tensile tested in accordance with Table 3, using wedge angles as specified in Table 5.

6.3 The hardness limits shall be met anywhere on the cross section through the threads, one diameter from the screw point as determined using Test Methods E 18.

7. Dimensions

7.1 Unless otherwise specified, the product shall conform to the requirements of ANSI B18.3.1M.

8. Workmanship, Finish, and Appearance

8.1 There shall be no evidence of carburization or gross decarburization on the surfaces of the heat-treated screws when measured in accordance with 10.2.

8.2 The depth of partial decarburization shall be limited to the values in Table 6 when measured as shown in Fig. 1, and in accordance with 10.2.

8.3 The surface discontinuities for these products shall conform to Specification F 788/F 788M and the additional limitations specified herein.

8.3.1 Forging defects that connect the socket to the periphery of the head are not permissible. Defects originating on the periphery and with a traverse indicating a potential to intersect and are not permissible. Other forging defects are permissible provided those located in the bearing area, fillet, and atop surfaces shall not have a depth exceeding 0.03D or 0.13 m, whichever is greater. For peripheral discontinuities, the maximum depth may be 0.06D, but not to exceed 1.6 mm (see Fig. 2).

8.3.2 Forging defects located in the socket wall within 0.1 times the actual key engagement (T) from the bottom of the socket are not permissible. Discontinuities located elsewhere in the socket shall not have a length exceeding 0.25 T, or a maximum depth of 0.03D not to exceed 0.13 mm (see Fig. 3).

8.3.3 Seams in the shank shall not exceed a depth of 0.03D or 0.2 mm, whichever is greater.

8.3.4 No transverse discontinuities shall be permitted in the head-to-shank fillet area.
8.3.5 Threads shall have no laps at the root or on the flanks, as shown in Fig. 4. Laps are permitted at the crest (Fig. 4C) that do not exceed 25% of the basic thread depth, and on the flanks outside the pitch cylinder. Longitudinal seams rolled beneath the root of the thread and across the crests of cut threads are acceptable within the limits of 8.3.3.

9. Number of Tests

9.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated. A record of individual heats of steel in each test lot shall be maintained. The container shall be coded to permit identification of the lot.

9.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last complete set of mechanical tests for each stock size in each shipment.

9.3 When additional tests are specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all screws offered for inspection at one time of one diameter

### TABLE 3  Mechanical Testing Requirements

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Tensile Load, (\text{min, kN})</th>
<th>Product Length</th>
<th>Hardness, max</th>
<th>Hardness, min</th>
<th>Decarburization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All short lengths (\ldots \leq 3D^A)</td>
<td>(b)</td>
<td>(b)</td>
<td>(b)</td>
<td>(\ldots)</td>
<td>(\ldots)</td>
</tr>
<tr>
<td>2</td>
<td>Smaller SHCS (\leq 1200) to 300 mm</td>
<td>(b)</td>
<td>(\ldots)</td>
<td>(b)</td>
<td>(Z^C)</td>
<td>(X^C)</td>
</tr>
<tr>
<td>3</td>
<td>Smaller SHCS (\leq 1200) Over 300 mm</td>
<td>(b)</td>
<td>(\ldots)</td>
<td>(b)</td>
<td>(\ldots)</td>
<td>(X^C)</td>
</tr>
<tr>
<td>4</td>
<td>Larger SHCS (\geq 1200) &gt;3D</td>
<td>(b)</td>
<td>(\ldots)</td>
<td>(b)</td>
<td>(Z^C)</td>
<td>(\ldots)</td>
</tr>
</tbody>
</table>

\(^A\) \(D\) denotes nominal diameter of product.
\(^b\) Denotes mandatory test.
\(^c\) Either all tests denoted by X or all tests denoted by Y shall be performed. In case of arbitration full-size tests, denoted X, shall be decisive. Proof test denoted Z shall be conducted when purchaser requests the test in inquiry and order.

### TABLE 4  Minimum Ultimate Tensile Loads

<table>
<thead>
<tr>
<th>Thread Size</th>
<th>Stress Area, (\text{mm}^2)</th>
<th>Tensile Load, (\text{min, kN})</th>
<th>Proof Load, (\text{kN})</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1.6 × 0.35</td>
<td>1.27</td>
<td>1.55</td>
<td>1.23</td>
</tr>
<tr>
<td>M2 × 0.4</td>
<td>2.07</td>
<td>2.53</td>
<td>2.01</td>
</tr>
<tr>
<td>M2.5 × 0.45</td>
<td>3.39</td>
<td>4.14</td>
<td>3.2</td>
</tr>
<tr>
<td>M3 × 0.5</td>
<td>5.03</td>
<td>6.14</td>
<td>4.88</td>
</tr>
<tr>
<td>M4 × 0.7</td>
<td>8.78</td>
<td>10.7</td>
<td>8.52</td>
</tr>
<tr>
<td>M5 × 0.8</td>
<td>14.2</td>
<td>17.3</td>
<td>13.8</td>
</tr>
<tr>
<td>M6 × 1</td>
<td>20.1</td>
<td>24.5</td>
<td>19.5</td>
</tr>
<tr>
<td>M8 × 1.25</td>
<td>36.6</td>
<td>44.6</td>
<td>35.5</td>
</tr>
<tr>
<td>M10 × 1.5</td>
<td>58.0</td>
<td>70.8</td>
<td>56.3</td>
</tr>
<tr>
<td>M12 × 1.75</td>
<td>84.3</td>
<td>103</td>
<td>81.8</td>
</tr>
<tr>
<td>M14 × 2</td>
<td>115</td>
<td>140</td>
<td>112</td>
</tr>
<tr>
<td>M16 × 2</td>
<td>157</td>
<td>192</td>
<td>152</td>
</tr>
<tr>
<td>M20 × 2.5</td>
<td>245</td>
<td>299</td>
<td>238</td>
</tr>
<tr>
<td>M24 × 3</td>
<td>353</td>
<td>431</td>
<td>342</td>
</tr>
<tr>
<td>M30 × 3.5</td>
<td>561</td>
<td>684</td>
<td>544</td>
</tr>
<tr>
<td>M36 × 4</td>
<td>817</td>
<td>997</td>
<td>792</td>
</tr>
<tr>
<td>M42 × 4.5</td>
<td>1120</td>
<td>1370</td>
<td>1090</td>
</tr>
<tr>
<td>M48 × 5</td>
<td>1470</td>
<td>1790</td>
<td>1430</td>
</tr>
</tbody>
</table>

**Note:** All values are rounded to 3 significant digits.

### TABLE 5  Wedge Test Angle

<table>
<thead>
<tr>
<th>Product</th>
<th>Diameter, mm</th>
<th>degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socket-head cap screws threaded 2D and closer to underside of head</td>
<td>through 20</td>
<td>6</td>
</tr>
<tr>
<td>All other socket-head cap screws</td>
<td>over 20 to 36</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>through 12</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>over 12 to 16</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>over 16 to 18</td>
<td>6</td>
</tr>
</tbody>
</table>

8.3.5 Threads shall have no laps at the root or on the flanks, as shown in Fig. 4. Laps are permitted at the crest (Fig. 4C) that do not exceed 25% of the basic thread depth, and on the flanks outside the pitch cylinder. Longitudinal seams rolled beneath the root of the thread and across the crests of cut threads are acceptable within the limits of 8.3.3.
FIG. 1 Decarburization Limits

Permissible in accordance with 8.3.1

Permissible in accordance with 8.3.1

Not permissible - potential interacting discontinuities

FIG. 2 Head and Body Discontinuity Location and Limits
and length. From each lot, the number of samples for each requirement shall be as follows:

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and less</td>
<td>1</td>
</tr>
<tr>
<td>Over 800 to 8 000, incl</td>
<td>2</td>
</tr>
<tr>
<td>Over 8 000 to 22 000, incl</td>
<td>3</td>
</tr>
<tr>
<td>Over 22 000</td>
<td>5</td>
</tr>
</tbody>
</table>

9.4 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be retested for the requirement(s) in which it failed. All of the additional samples shall conform to the specification or the lot shall be rejected.

10. Test Methods

10.1 Conduct tests for proof load, wedge tensile, and ultimate tensile strength in accordance with Test Methods F 606M.

10.2 Decarburization and carburization tests shall be conducted as follows:

10.2.1 Section the thread area of the bolt longitudinally through the axis, mount, and polish it in accordance with Methods E 3. Take measurements (1) at the minor diameter in the center of the thread ridge and (2) 0.75 \( h \) toward the thread crest on the perpendicular bisector of the thread ridge. Take a
measurement (3) on the thread flank approximately at the pitch line at a depth of 0.08 mm. Use one of the two methods for carburization/decarburization evaluation either optical or microhardness measurements. The microhardness measurement shall constitute a referee method in case of dispute.

10.2.2 For optical measurement, etch the section in 2 – 4% nital. Examine the surface of the etched samples under a microscope at 100× using a measuring eyepiece graduated in 0.03-mm increments. The width of any light etching band normally defines the decarburization depth. A dark etching band indicates the possibility of carburization.

10.2.3 Measure microhardness in accordance with Test Method E 384 on unetched specimens using a DPH 136° indenter or a Knoop indenter using the following load application:

<table>
<thead>
<tr>
<th>Thread Pitch, P min.</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 0.6</td>
<td>500 gf</td>
</tr>
<tr>
<td>0.6</td>
<td>200 gf</td>
</tr>
<tr>
<td>Less than 0.6</td>
<td>Use optical evaluation in 10.3.2</td>
</tr>
</tbody>
</table>

10.2.3.1 Take measurements at minor diameter (Reading No. 1) on the thread crest bisector to determine base metal hardness. Take measurements (Reading No. 2) on the bisector 0.75 h from the minor measurement toward the thread crest. Also take measurements (Reading No. 3) on the thread flank at the pitch line at a depth within 0.08 mm from the surface. Reading No. 3 may be taken on the same or an adjacent thread.

10.2.4 Interpret microhardness readings as follows:

10.2.4.1 A decrease of more than 30 hardness points from Reading No. 1 to Reading No. 2 shall be regarded as decarburization and indicates the screw does not conform to specification requirements.

10.2.4.2 An increase of more than 30 hardness points from Reading No. 1 to Reading No. 3 shall be regarded as carburization and indicates that the screw does not conform to specification requirements.

11. Inspection

11.1 If the additional tests described in 9.3 are required by the purchaser, it shall be specified in the inquiry, order, or contract.

11.2 The inspector representing the purchaser, upon reasonable notice, shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection required by the specification that are requested by the purchaser’s representative shall be made before shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

12. Product Marking

12.1 All screws with nominal diameters of 5 mm and larger shall be permanently marked to identify the property class, 12.9 and the manufacturer’s or private label distributor’s identification symbol. Marking for “Socket Head Cap Screws” may be on the side of the head or on top.

12.2 Property class and manufacturer’s or private label distributor’s identification shall be separate and distinct. Marks shall preferably be in different locations and, when on the same level, shall be separated by a distinctive mark such as a forward or backward slash, colon, dash, dot, or space.

13. Responsibility

13.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

14. Packaging and Package Marking

14.1 Packaging:

14.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

14.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

14.2 Package Marking:

14.2.1 Each shipping unit shall include or be plainly marked with the following information:

14.2.1.1 ASTM designation,
14.2.1.2 Size,
14.2.1.3 Name brand or trademark of the manufacturer,
14.2.1.4 Number of pieces,
14.2.1.5 Purchase order number, and
14.2.1.6 Country of origin.

15. Keywords

15.1 alloy steel; cap screws; socket head
SUPPLEMENTARY REQUIREMENTS

The following Supplementary Requirement shall apply only when specified by the purchaser in the contract or purchase order. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Specific Grade Chemical Compositions

S1.1 When Supplementary Requirement S1 is specified on the order, the chemical composition shall conform to one of the compositions in Table S1.1 at the option of the supplier, unless a specific composition (Grade) has been specified on the purchase order.

<table>
<thead>
<tr>
<th>Table S1.1 Chemical Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade Designation</td>
</tr>
<tr>
<td>UNS Number</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Manganese:</td>
</tr>
<tr>
<td>Heat Analysis</td>
</tr>
<tr>
<td>Product Analysis</td>
</tr>
<tr>
<td>Phosphorus, max.:</td>
</tr>
<tr>
<td>Heat Analysis</td>
</tr>
<tr>
<td>Product Analysis</td>
</tr>
<tr>
<td>Sulfur, max.:</td>
</tr>
<tr>
<td>Heat Analysis</td>
</tr>
<tr>
<td>Product Analysis</td>
</tr>
<tr>
<td>Silicon:</td>
</tr>
<tr>
<td>Heat Analysis</td>
</tr>
<tr>
<td>Product Analysis</td>
</tr>
<tr>
<td>Nickel:</td>
</tr>
<tr>
<td>Heat Analysis</td>
</tr>
<tr>
<td>Product Analysis</td>
</tr>
<tr>
<td>Chromium:</td>
</tr>
<tr>
<td>Heat Analysis</td>
</tr>
<tr>
<td>Product Analysis</td>
</tr>
<tr>
<td>Molybdenum:</td>
</tr>
<tr>
<td>Heat Analysis</td>
</tr>
<tr>
<td>Product Analysis</td>
</tr>
<tr>
<td>Boron:</td>
</tr>
<tr>
<td>Heat Analysis</td>
</tr>
<tr>
<td>Product Analysis</td>
</tr>
</tbody>
</table>

Elements shown with an “A” are not applicable to that grade designation. Boron is not subject to product analysis.

SUMMARY OF CHANGES

This section identifies the location of changes to this specification that have been incorporated since the —98a issue. Committee F16 has highlighted those changes that affect the technical interpretation or use of this specification.

(1) Added 3.2.8, providing for optional use of ASME B18.24.1, Part Identifying Number (PIN) Code System.
1. Scope*

1.1 This specification covers the requirements for quenched and tempered alloy steel socket-head cap screws 1.6 mm through 48 mm in diameter having a minimum ultimate tensile strength of 1220 MPa.

NOTE 1—This specification is the metric companion of Specification A 574.

1.2 The following hazard caveat pertains only to the test method portion, Section 10, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

*This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.02 on Steel Bolts, Nuts, Rivets, and Washers.

3. Ordering Information

3.1 Orders for socket head cap screws under this specification shall include the following information:

3.1.1 Quantity (number of screws),
3.1.2 Dimensions, including nominal thread designation, thread, pitch, and nominal screw length (millimetres),
3.1.3 Name of the screw (SHCS),
3.1.4 ASTM designation and year of issue.

3.2 Orders for socket head cap screws may include the following optional requirements:

3.2.1 Inspection at point of manufacture.
3.2.2 Coating, if required (see 4.6).
3.2.3 Certified Test Reports (see 9.2).
3.2.4 Additional Testing (see 9.3 and 11.1).
3.2.5 Special Packaging (see 14.1.2).
3.2.6 Supplementary Requirement (see S1).
3.2.7 Special Requirements.
3.2.8 For establishment of a part identifying system, see ASME B18.24.1.

4. Materials and Manufacture

4.1 The screws shall be fabricated from steel made to fine grain practice. In the event of controversy over grain size, referee tests on finished screws conducted in accordance with Test Method E 112 shall prevail.

4.2 Screws in sizes up to M20 inclusive, and with lengths up to 10 times the nominal product size or 150 mm, whichever is shorter, shall be cold headed, except that they may be hot headed by agreement of the purchaser. Larger sizes and longer lengths may be cold or hot headed. Screws M42 and larger may be machined. Sockets may be forged or machined at the option of the manufacturer.

4.3 Screws in sizes up to M24 inclusive, and product lengths up to 150 mm inclusive, shall be roll threaded, except by special agreement of the purchaser. Larger products may be rolled, cut, or ground at the option of the manufacturer.

4.4 Socket-head cap screws shall be heat treated by quenching in oil from above the transformation temperature and then tempered by reheating to at least 380°C to within the hardness range specified in Table 1.

4.4.1 The minimum tempering temperature may be verified by submitting screws to 370°C for 30 min at temperature. The mean cross section hardness of three readings on the screw before and after retempering shall not differ by more than 20 DPH.

4.5 Standard Finishes—Unless otherwise specified, the screws shall be furnished with one of the following “standard surfaces as manufactured”, at the option of the manufacturer; (1) bright uncoated, (2) thermal black oxide, or (3) chemical black oxide. Hydrogen embrittlement tests shall not be required for screws furnished in these conditions.

4.6 Protective Coatings:

4.6.1 When a protective finish other than as specified in 4.5 is required, it shall be specified on the purchase order with the applicable finish specification.

4.6.2 When protective or decorative coatings are applied to the screws, precautions specified by the coating requirements to minimize embrittlement shall be exercised.

5. Chemical Composition

5.1 The screws shall be alloy steel conforming to the chemical composition specified in Table 2. See Supplementary Requirement S1 when specific chemistry grades are required.

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Footnotes:

2 Annual Book of ASTM Standards, Vol 01.03.
4 Annual Book of ASTM Standards, Vol 03.01.
5 Annual Book of ASTM Standards, Vol 01.08.
6 Available from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.
7 Available from American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016–5990.
5.2 One or more of the following alloying elements: chromium, nickel, molybdenum, or vanadium shall be present in the steel in sufficient quantity to ensure the specified strength properties are met after oil quenching and tempering. As a guide for selecting material, an alloy steel should be capable of meeting the specified mechanical requirements if the “as oil quenched” core hardness one diameter from the point is equal to or exceeds 25 HRC + (55 × carbon content).

5.3 Product analyses may be made by the purchaser from finished screws representing each lot. The chemical composition thus determined shall conform to the requirements specified for the product analysis in Table 2.

5.4 Steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

5.5 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 Socket head cap screws shall be tested in accordance with the mechanical testing requirements specified in Table 3, and shall meet the mechanical requirements in Table 1 and Table 4.

### TABLE 1 Mechanical Requirements

<table>
<thead>
<tr>
<th>Property class</th>
<th>12.9&lt;br&gt;^A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full-size screws:&lt;br&gt;Tensile or wedge strength, min, MPa</td>
<td>1220</td>
</tr>
<tr>
<td>Proof load (stress), min, MPa</td>
<td>970</td>
</tr>
<tr>
<td>Machined test specimen:&lt;br&gt;Yield strength at 0.2 % offset, min, MPa</td>
<td>1100</td>
</tr>
<tr>
<td>Tensile strength, min, MPa</td>
<td>1220</td>
</tr>
<tr>
<td>Elongation in 5D, min, %</td>
<td>10&lt;br&gt;^A</td>
</tr>
<tr>
<td>Reduction of area, min, %</td>
<td>35</td>
</tr>
<tr>
<td>Product hardness:&lt;br&gt;Rockwell</td>
<td>38 to 44 HRC</td>
</tr>
<tr>
<td>Vickers</td>
<td>372 to 434 DPH</td>
</tr>
</tbody>
</table>

^A Elongation is 2 percentage points higher than property class 12.9.

### TABLE 2 Chemical Requirements

<table>
<thead>
<tr>
<th>Element</th>
<th>Composition, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Analysis</td>
<td>Product Analysis</td>
</tr>
<tr>
<td>Carbon</td>
<td>0.33 to 0.48</td>
</tr>
<tr>
<td>Phosphorus, max</td>
<td>0.035</td>
</tr>
<tr>
<td>Sulfur, max</td>
<td>0.040</td>
</tr>
<tr>
<td>Alloying elements</td>
<td>See 5.2</td>
</tr>
</tbody>
</table>

### TABLE 3 Mechanical Testing Requirements

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Tensile Load, min, kN</th>
<th>Product Length</th>
<th>Hardness, max</th>
<th>Hardness, min</th>
<th>Decarburization</th>
<th>Test Conducted Using Full-Size Product</th>
<th>Test Conducted using Machined Test Specimen</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All short lengths</td>
<td>≤3D&lt;br&gt;^A</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>Proof Load, Axial Tensile Strength at 0.2 % Offset, Elongation, Reduction of Area</td>
</tr>
<tr>
<td>2</td>
<td>Smaller SHCS ≤1200</td>
<td>3D to 300 mm</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>Proof Load, Wedge Tensile Strength, Axial Tensile Strength, Elongation, Reduction of Area</td>
</tr>
<tr>
<td>3</td>
<td>Smaller SHCS ≤1200</td>
<td>Over 300 mm</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>Proof Load, Wedge Tensile Strength, Axial Tensile Strength, Elongation, Reduction of Area</td>
</tr>
<tr>
<td>4</td>
<td>Larger SHCS ≥1200</td>
<td>&gt;3D</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>Proof Load, Wedge Tensile Strength, Axial Tensile Strength, Elongation, Reduction of Area</td>
</tr>
</tbody>
</table>

^A D denotes nominal diameter of product.<br>^B Denotes mandatory test.<br>^C Either all tests denoted by X or all tests denoted by Y shall be performed. In case of arbitration full-size tests, denoted X, shall be decisive. Proof test denoted Z shall be conducted when purchaser requests the test in inquiry and order.
6.2 Screws in sizes 1.6 through 36-mm diameter shall be wedge tensile tested in accordance with Table 3, using wedge angles as specified in Table 5.

6.3 The hardness limits shall be met anywhere on the cross section through the threads, one diameter from the screw point as determined using Test Methods E 18.

7. Dimensions

7.1 Unless otherwise specified, the product shall conform to the requirements of ANSI B18.3.1M.

8. Workmanship, Finish, and Appearance

8.1 There shall be no evidence of carburization or gross decarburization on the surfaces of the heat-treated screws when measured in accordance with 10.2.

8.2 The depth of partial decarburization shall be limited to the values in Table 6 when measured as shown in Fig. 1, and in accordance with 10.2.

8.3 The surface discontinuities for these products shall conform to Specification F 788/F 788M and the additional limitations specified herein.

8.3.1 Forging defects that connect the socket to the periphery of the head are not permissible. Defects originating on the periphery and with a traverse indicating a potential to intersect and are not permissible. Other forging defects are permissible provided those located in the bearing area, fillet, and top surfaces shall not have a depth exceeding 0.03D or 0.13 m, whichever is greater. For peripheral discontinuities, the maximum depth may be 0.06D, but not to exceed 1.6 mm (see Fig. 2).

8.3.2 Forging defects located in the socket wall within 0.1 times the actual key engagement (T) from the bottom of the socket are not permissible. Discontinuities located elsewhere in the socket shall not have a length exceeding 0.25T, or a maximum depth of 0.03D not to exceed 0.13 mm (see Fig. 3).

8.3.3 Seams in the shank shall not exceed a depth of 0.03D or 0.2 mm, whichever is greater.

8.3.4 No transverse discontinuities shall be permitted in the head-to-shank fillet area.

8.3.5 Threads shall have no laps at the root or on the flanks, as shown in Fig. 4. Laps are permitted at the crest (Fig. 4C) that do not exceed 25% of the basic thread depth, and on the flanks outside the pitch cylinder. Longitudinal seams rolled beneath the root of the thread and across the crests of cut threads are acceptable within the limits of 8.3.3.

8.3.6 Quench cracks of any depth, any length, or in any location are not permitted.

9. Number of Tests

9.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make

### Table 4: Minimum Ultimate Tensile Loads

<table>
<thead>
<tr>
<th>Thread Size</th>
<th>Stress Area, mm²</th>
<th>Tensile Load, min, kN</th>
<th>Proof Load, kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1.6 × 0.35</td>
<td>1.27</td>
<td>1.55</td>
<td>1.23</td>
</tr>
<tr>
<td>M2 × 0.4</td>
<td>2.07</td>
<td>2.53</td>
<td>2.01</td>
</tr>
<tr>
<td>M2.5 × 0.45</td>
<td>3.39</td>
<td>4.14</td>
<td>3.2</td>
</tr>
<tr>
<td>M3 × 0.5</td>
<td>5.03</td>
<td>6.14</td>
<td>4.88</td>
</tr>
<tr>
<td>M4 × 0.7</td>
<td>8.78</td>
<td>10.7</td>
<td>8.52</td>
</tr>
<tr>
<td>M5 × 0.8</td>
<td>14.2</td>
<td>17.3</td>
<td>13.8</td>
</tr>
<tr>
<td>M6 × 1</td>
<td>20.1</td>
<td>24.5</td>
<td>19.5</td>
</tr>
<tr>
<td>M8 × 1.25</td>
<td>36.6</td>
<td>44.6</td>
<td>35.5</td>
</tr>
<tr>
<td>M10 × 1.5</td>
<td>58.0</td>
<td>70.8</td>
<td>56.3</td>
</tr>
<tr>
<td>M12 × 1.75</td>
<td>84.3</td>
<td>103</td>
<td>81.8</td>
</tr>
<tr>
<td>M14 × 2</td>
<td>115</td>
<td>140</td>
<td>112</td>
</tr>
<tr>
<td>M16 × 2</td>
<td>157</td>
<td>192</td>
<td>152</td>
</tr>
<tr>
<td>M20 × 2.5</td>
<td>245</td>
<td>299</td>
<td>238</td>
</tr>
<tr>
<td>M24 × 3</td>
<td>353</td>
<td>431</td>
<td>342</td>
</tr>
<tr>
<td>M30 × 3.5</td>
<td>561</td>
<td>684</td>
<td>544</td>
</tr>
<tr>
<td>M36 × 4</td>
<td>817</td>
<td>997</td>
<td>792</td>
</tr>
<tr>
<td>M42 × 4.5</td>
<td>1120</td>
<td>1370</td>
<td>1090</td>
</tr>
<tr>
<td>M48 × 5</td>
<td>1470</td>
<td>1790</td>
<td>1430</td>
</tr>
</tbody>
</table>

### Table 5: Wedge Test Angle

<table>
<thead>
<tr>
<th>Product</th>
<th>Diameter, mm</th>
<th>degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socket-head cap screws threaded 2D and closer to underside of head</td>
<td>through 20 and over 20 to 36</td>
<td>6</td>
</tr>
<tr>
<td>All other socket-head cap screws</td>
<td>through 12 and over 12 to 16</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>over 16 to 36</td>
<td>8</td>
</tr>
</tbody>
</table>
sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated. A record of individual heats of steel in each test lot shall be maintained. The container shall be coded to permit identification of the lot.

9.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last complete set of mechanical tests for each stock size in each shipment.

9.3 When additional tests are specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all screws offered for inspection at one time of one diameter and length. From each lot, the number of samples for each requirement shall be as follows:

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and less</td>
<td>1</td>
</tr>
<tr>
<td>Over 800 to 8,000, incl</td>
<td>2</td>
</tr>
<tr>
<td>Over 8,000 to 22,000, incl</td>
<td>3</td>
</tr>
<tr>
<td>Over 22,000</td>
<td>5</td>
</tr>
</tbody>
</table>

9.4 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be retested for the requirement(s) in which it failed. All of the additional samples shall conform to the specification or the lot shall be rejected.

10. Test Methods

10.1 Conduct tests for proof load, wedge tensile, and ultimate tensile strength in accordance with Test Methods F 606M.
10.2 Decarburization and carburization tests shall be conducted as follows:

10.2.1 Section the thread area of the bolt longitudinally through the axis, mount, and polish it in accordance with Methods E 3. Take measurements (1) at the minor diameter in the center of the thread ridge and (2) 0.75 \( h \) toward the thread crest on the perpendicular bisector of the thread ridge. Take a measurement (3) on the thread flank approximately at the pitch line at a depth of 0.08 mm. Use one of the two methods for carburization/decarburization evaluation either optical or microhardness measurements. The microhardness measurement shall constitute a referee method in case of dispute.
10.2.2 For optical measurement, etch the section in 2 – 4% nital. Examine the surface of the etched samples under a microscope at 100× using a measuring eyepiece graduated in 0.03-mm increments. The width of any light etching band normally defines the decarburization depth. A dark etching band indicates the possibility of carburization.

10.2.3 Measure microhardness in accordance with Test Method E 384 on unetched specimens using a DPH 136° indenter or a Knoop indenter using the following load application:

<table>
<thead>
<tr>
<th>Thread Pitch, P min.</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 0.6</td>
<td>500 gf</td>
</tr>
<tr>
<td>0.6</td>
<td>200 gf</td>
</tr>
<tr>
<td>Less than 0.6</td>
<td>Use optical evaluation in 10.3.2</td>
</tr>
</tbody>
</table>

10.2.3.1 Take measurements at minor diameter (Reading No. 1) on the thread crest bisector to determine base metal hardness. Take measurements (Reading No. 2) on the bisector 0.75 h from the minor measurement toward the thread crest. Also take measurements (Reading No. 3) on the thread flank at the pitch line at a depth within 0.08 mm from the surface. Reading No. 3 may be taken on the same or an adjacent thread.

10.2.4 Interpret microhardness readings as follows:
10.2.4.1 A decrease of more than 30 hardness points from Reading No. 1 to Reading No. 2 shall be regarded as decarburization and indicates the screw does not conform to specification requirements.
10.2.4.2 An increase of more than 30 hardness points from Reading No. 1 to Reading No. 3 shall be regarded as carburization and indicates that the screw does not conform to specification requirements.

11. Inspection
11.1 If the additional tests described in 9.3 are required by the purchaser, it shall be specified in the inquiry, order, or contract.
11.2 The inspector representing the purchaser, upon reasonable notice, shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection required by the specification that are requested by the purchaser’s representative shall be made before shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

12. Product Marking
12.1 All screws with nominal diameters of 5 mm and larger shall be permanently marked to identify the property class, 12.9 and the manufacturer’s or private label distributor’s identification symbol. Marking for “Socket Head Cap Screws” may be on the side of the head or on top.
12.2 Property class and manufacturer’s or private label distributor’s identification shall be separate and distinct. Marks shall preferably be in different locations and, when on the same level, shall be separated by a distinctive mark such as a forward or backward slash, colon, dash, dot, or space.

13. Responsibility
13.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.
14. Packaging and Package Marking

14.1 Packaging:
14.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.
14.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

14.2 Package Marking:
14.2.1 Each shipping unit shall include or be plainly marked with the following information:
14.2.1.1 ASTM designation,
14.2.1.2 Size,
14.2.1.3 Name brand or trademark of the manufacturer,
14.2.1.4 Number of pieces,
14.2.1.5 Purchase order number, and
14.2.1.6 Country of origin.

15. Keywords
15.1 alloy steel; cap screws; socket head

SUPPLEMENTARY REQUIREMENTS

The following Supplementary Requirement shall apply only when specified by the purchaser in the contract or purchase order. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Specific Grade Chemical Compositions

S1.1 When Supplementary Requirement S1 is specified on the order, the chemical composition shall conform to one of the compositions in Table S1.1 at the option of the supplier, unless a specific composition (Grade) has been specified on the purchase order.

| TABLE S1.1 Chemical Composition |
|------------------------- |----------------- |----------------- |----------------- |----------------- |----------------- |----------------- |----------------- |----------------- |
| Grade Designation | 4037 | 4042 | 4137 | 4140 | 4142 | 4145 | 4340 | 8740 | 5137M | 51B37M |
| UNS Number | G40370 | G40420 | G41370 | G41400 | G41420 | G41450 | G43400 | G87400 | . . . | . . . |
| Carbon: | | | | | | | | | | |
| Heat Analysis | 0.35–0.40 | 0.35–0.40 | 0.35–0.40 | 0.35–0.40 | 0.35–0.40 | 0.35–0.40 | 0.35–0.40 | 0.35–0.40 | 0.35–0.40 | 0.35–0.40 |
| Product Analysis | 0.33–0.42 | 0.33–0.42 | 0.33–0.42 | 0.33–0.42 | 0.33–0.42 | 0.33–0.42 | 0.33–0.42 | 0.33–0.42 | 0.33–0.42 | 0.33–0.42 |
| Manganese: | | | | | | | | | | |
| Heat Analysis | 0.70–0.90 | 0.70–0.90 | 0.70–0.90 | 0.70–0.90 | 0.70–0.90 | 0.70–0.90 | 0.70–0.90 | 0.70–0.90 | 0.70–0.90 | 0.70–0.90 |
| Product Analysis | 0.67–0.93 | 0.67–0.93 | 0.67–0.93 | 0.67–0.93 | 0.67–0.93 | 0.67–0.93 | 0.67–0.93 | 0.67–0.93 | 0.67–0.93 | 0.67–0.93 |
| Phosphorus, max.: | | | | | | | | | | |
| Heat Analysis | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 |
| Product Analysis | 0.040 | 0.040 | 0.040 | 0.040 | 0.040 | 0.040 | 0.040 | 0.040 | 0.040 | 0.040 |
| Sulfur, max.: | | | | | | | | | | |
| Heat Analysis | 0.040 | 0.040 | 0.040 | 0.040 | 0.040 | 0.040 | 0.040 | 0.040 | 0.040 | 0.040 |
| Product Analysis | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 |
| Silicon: | | | | | | | | | | |
| Heat Analysis | 0.15–0.35 | 0.15–0.35 | 0.15–0.35 | 0.15–0.35 | 0.15–0.35 | 0.15–0.35 | 0.15–0.35 | 0.15–0.35 | 0.15–0.35 | 0.15–0.35 |
| Product Analysis | 0.13–0.37 | 0.13–0.37 | 0.13–0.37 | 0.13–0.37 | 0.13–0.37 | 0.13–0.37 | 0.13–0.37 | 0.13–0.37 | 0.13–0.37 | 0.13–0.37 |
| Nickel: | | | | | | | | | | |
| Heat Analysis | A | A | A | A | A | A | A | A | A | A |
| Product Analysis | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . |
| Chromium: | | | | | | | | | | |
| Heat Analysis | A | A | 0.80–1.10 | 0.80–1.10 | 0.80–1.10 | 0.80–1.10 | 0.70–0.90 | 0.40–0.60 | 0.90–1.20 | 0.95–1.25 |
| Product Analysis | . . . | . . . | 0.75–1.15 | 0.75–1.15 | 0.75–1.15 | 0.75–1.15 | 0.67–0.93 | 0.37–0.63 | 0.85–1.25 | 0.90–1.30 |
| Molybdenum: | | | | | | | | | | |
| Heat Analysis | 0.20–0.30 | 0.20–0.30 | 0.15–0.25 | 0.15–0.25 | 0.15–0.25 | 0.15–0.25 | 0.20–0.30 | 0.20–0.30 | 0.20–0.30 | 0.20–0.30 |
| Product Analysis | 0.18–0.32 | 0.18–0.32 | 0.13–0.27 | 0.13–0.27 | 0.13–0.27 | 0.13–0.27 | 0.18–0.32 | 0.18–0.32 | 0.18–0.32 | 0.18–0.32 |
| Boron: | | | | | | | | | | |
| Heat Analysis | A | A | A | A | A | A | A | A | A | A |
| Product Analysis | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . |

Elements shown with an "A" are not applicable to that grade designation.
Boron is not subject to product analysis.
SUMMARY OF CHANGES

This section identifies the location of changes to this specification that have been incorporated since the —98a issue. Committee F-16 has highlighted those changes that affect the technical interpretation or use of this specification.

(1) Added 4.5, defining the standard as manufactured finishes.
(2) Added 4.6, 3.2.8, providing for specifying other protective coatings.
(3) In 4.6.2 (formerly 4.5), deleted the embrittlement test and changed “prevent embrittlement” to “minimize embrittlement”.

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Standard Test Method for
Determining Life and Torque of Lubricating Greases in Small Ball Bearings

1

This standard is issued under the fixed designation D 3337; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1 Scope

1.1 This test method describes a procedure for the determination of grease life and torque in small bearings. Although this test method is not the equivalent of a long-time field-service test, it is intended to predict the relative grease life at high temperature in a reasonable period of testing time. In addition, this test method measures the running torque at both low (1 r/min) and high (12 000 r/min) speeds.

1.2 Except for torque, which is measured in g·cm, the values stated in inch-pound units are to be regarded as the standard in this test method. The SI values given in parenthesis are for information only.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 Terminology

2.1 Definitions of Terms Specific to This Standard:

2.1.1 grease life—a measure of the durability of the grease in a small bearing at elevated temperatures.

2.1.2 grease torque—a measure of the amount of friction due to viscous shear of the grease.

2.1.3 running torque—a measure of the amount of friction in a rotating bearing due to load, speed, and viscous shear of the grease.

3 Summary of Test Method

3.1 A single row ball bearing with the test lubricating grease is rotated at a high speed under a constant load and selected temperature. Total running time is determined at completion of the test as a measure of the durability of the grease.

3.2 Running torque can be obtained for a single row ball bearing with the test lubricating grease rotating at 1 r/min and 12 000 r/min.

4 Significance and Use

4.1 This test method is a screening test to differentiate among the expected life of greases in ball bearings running at high temperatures. If torque is a factor in selection of a grease, the test method provides for measurements at both low (1 r/min) and high (12 000 r/min) speeds.

5 Apparatus

5.1 The apparatus required for this test method is described in detail in Annex A1. A new R-4 bearing is used for each test. It is run at 12 000 r/min ½-lbf (2.2-N) radial load and 5-lbf (22-N) axial load.

6 Reagents and Materials

6.1 Grease Sample—Procure the grease sample from below the surface of the grease container. Do not let separated oil get in contact with the sample; pour the excess oil off if present. Screen the grease using a 40-µm retention filter. A technique for screening is described in Annex A2.

6.2 Test Bearing:

6.2.1 Specifications—the test bearing is size R-4.

6.2.2 Size—0.2500 in. (6.350 mm) bore, 0.6250 in. (15.875 mm) OD, 0.1960 in. (4.978 mm) wide.

6.2.3 Material—Type 440C stainless steel, heat stabilized.

6.2.4 Precision Class—AFBMA (Anti-Friction Bearing Manufacturers Association) Class 7.

6.2.5 Radial Clearance—0.0003 to 0.0005 in. (0.007 to 0.013 mm).

6.2.6 Retainer—stainless steel ribbon type.

6.2.7 Shields—removable with snap rings.

6.2.8 Packaging—bearing, shields, and snap rings packaged individually in clean and sealed envelopes.

7 Grease Packing of Test Bearing

7.1 Pack the test bearing in a clean environment with a quantity of test grease to fill one third of the free space in the bearing.
7.2 If it is necessary to determine the free space of a weighed bearing, place the bearing (with shields and snap rings removed) in a container of melted petrolatum of known density under vacuum. Let the petrolatum harden, remove bearing, and replace shields and snap rings. Clean the bearing of excess petrolatum and determine the weight increase. Using the density of petrolatum and bearing weight increase, compute the bearing free space. For the Barden bearing No. SR4SSW4, the one-third free space is 0.080 mL.

7.3 The test bearing may be packed on either a weight or a volume basis. A small spatula or a small syringe\(^3\) with a short needle can be used to place the test grease between the balls on both sides of the test bearing.

7.4 If the test bearing is packed on a weight basis, the density of the grease must be known in order to compute the weight of test grease equivalent to one-third the free space in the test bearing.

7.5 Immediately after packing the test grease in the test bearing, install the shields and snap rings. Then turn the bearing 100 revolutions in each direction at less than 200 rpm to distribute the test grease.

8. Procedure

8.1 This procedure describes removal of a used test bearing, installation of a new test bearing, start-up technique, and test monitoring.

8.1.1 Test Bearing Removal:

8.1.1.1 Remove the heater box.

8.1.1.2 Unlatch the radial and axial bead chains from the cantilever beams and unplug the test-bearing outer-race thermocouple cable from the post at the side of the tester.

8.1.1.3 Remove the nose cone by removing the four screws which attach it to the test-bearing housing.

8.1.1.4 Using two small wrenches, one on the test-bearing lock nut and one on the spindle flats next to the nut, loosen the test-bearing lock nut. This is done safely by having the wrench handles about 20 deg apart and squeezing them toward each other to avoid a bending moment on the overhanging end of the spindle.

8.1.1.5 Remove the test-bearing lock nut.

8.1.1.6 Slide the test bearing housing off the end of the spindle and lift slowly in a vertical direction until the torque arm, its bead chain, and the thermocouple wires with plug clear the slot in the mounting plate. Do not remove the slinger.

8.1.1.7 Push (Note 1) the used test bearing out of its housing.

8.1.2.1 With the spring-loaded thermocouple retracted, push a new test bearing into the housing. Use the nose cone to seat the test bearing fully. This avoids thumb pressure on the inner race and shields which can damage the bearing.

8.1.2.2 Hold the housing up above the tester and let the thermocouple plug with wires and the radial bead chain drop down through the slot in the mounting plate. Caution: Use care to ensure that the transducer-core extension is not bumped and that the thermocouple lead wires are not bent to prevent erroneous data.

8.1.2.3 Slide the test bearing and housing over the end of the spindle until the test bearing seats against the slinger.

8.1.2.4 Insert the thermocouple plug and attach the radial bead chain to its cantilever with three beads below the beam.

8.1.2.5 Install the test-bearing lock nut (Note 2) finger tight with the shoulder end toward the test bearing. Then fully tighten the nut using two small wrenches and following the technique in 8.1.1.4.

Note 2—If the test bearing runs at temperatures above 300°F (150°C), lubricate the nut and screw threads with a solid lubricant such as molybdenum disulfide to prevent thread galling.

8.1.2.6 Attach the nose cone with the bead chain slot upward using the four small screws.

8.1.2.7 Attach the axial bead chain to its cantilever beam with three beads beyond the beam.

8.1.2.8 Using a 0 to 5-lbf (0 to 22-N) spring scale, check the cantilever beams (Note 3) for ½-lbf (2.2-N) radial loading and 5-lbf axial loading.

Note 3—Cantilever beam loads can be changed by bending the beams. After bending, use a 6-in. (150 mm) machinist square and a straighthedge to ensure that the radial-bead chain is perpendicular to the base and that the axial bead chain is in line with the centerline of the spindle.

8.1.2.9 Check the thermocouple lead wires to be sure they are freely suspended and smoothly contoured from the torque arm to the plug.

8.1.2.10 Carefully place the heater box over the test-bearing housing.

8.1.3 Start-up Technique:

8.1.3.1 To relieve drive-belt tension, prop up the pivoted-drive motor using a block of wood.

8.1.3.2 Turn the run-time meter to zero.

8.1.3.3 Set the cycle timer to 20 % (zero to 17 % is the 4-h shutdown interval).

8.1.3.4 Set the torque-meter cut-off at 80 % of full scale.

8.1.3.5 Set the temperature controller (left-hand pointer) to about 20°F (10°C) below the intended outer-race test-bearing temperature. Set and maintain the over-temperature cut-off (right-hand pointer) 15°F (9°C) above the control temperature (the temperature controller is connected to the thermocouple in the heater box).

8.1.3.6 Turn on the following switches: 110 V a-c, torque, heater, and high-speed motor. Then push the start button to activate circuits.

8.1.3.7 Gradually slide the prop out from under the drive-motor base until the spindle runs at low speed with a slack belt. Finger pressure on the spindle aids in keeping a low speed. Run for about ½ min at low speed before removing the prop to bring the spindle up to test speed.

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\(^3\) A suitable micrometer syringe is Catalog No. N-07844-00, 0.2-mL capacity, manufactured by Cole-Parmer Instruments Co., 7425 North Oak Park Ave., Chicago, IL 60648.
8.1.4 Test Monitoring:

8.1.4.1 After 1 h of test operation at high speed and control temperature, measure the temperature of the outer race of the test bearing. Adjust the controller such that the outer race of the test bearing is at test temperature for the grease. Additional controller adjustment may be required during the first 40 h of operation.

8.1.4.2 After 2 h of test operation at high speed and control temperature, stop the drive motor and prop it up to remove belt tension. Adjust the torque table so that the torque meter reads two to four units up-scale (torque-meter tare) by gently tapping the bead chains with a pencil during the torque table adjustment to minimize the torque-meter tare error due to static friction in the bearings. This ensures torque-transducer contact with the torque arm. Restart the testers and run for another hour before recording data.

8.1.4.3 Record test hours, torque-meter tare, torque-meter reading, net torque, torque in g-cm from calibration curve, control temperature, and outer-race temperature of the test bearing at least once every 24 h. Calibration of torque instrumentation is in A1.5. Torque data for both high-speed and one-r/min operation are to be recorded. After the first recording, set the torque meter cut-off at five times this running torque.

8.1.4.4 To keep the tester running for 30 s when over-torque occurs at start-up, hold the arm away from the transducer core by light finger pressure on the radial bead chain.

8.1.4.5 During the early part of the test at high speed, excessive bead-chain vibration, torque fluctuation greater than ±2 g-cm, or torque greater than twice the normal running torque for the grease may be observed. If any of these occur, stop the test and restart using a new test bearing.

9. Results

9.1 Termination of the test is determined by any one of the following conditions:

9.1.1 Instantaneous over-torque of five times the minimum running torque at high speed and test temperature, or over-torque of five times the minimum running torque if it continues for more than 30 s at high-speed start-up in the test cycle.

9.1.2 Over-temperature of 20°F (11°C) at the outer race of the test bearing.

9.1.3 Noise level increase that persists for more than 1 min either at start-up or running at high speed.

10. Report

10.1 Report test results and test conditions on the report form shown in Table 1.

11. Precision and Bias

11.1 The precision of this test is not known to have been obtained in accordance with currently accepted guidelines (for example, in Committee D-2 Research Report RR: D02-1007, Manual on Determining Precision Data for ASTM Methods on Petroleum Products and Lubricants).

11.2 Grease life data generated in cooperative testing using this procedure show appreciable scatter and were found to conform in the general case to Weibull probability distributions rather than normal distributions. Conventional ASTM definitions of repeatability and reproducibility are meaningful only for data that can be described by normal distributions and, therefore, are not appropriate. Weibull parameters such as slope, \( L_{10} \) and \( L_{50} \), are used to describe the distribution of the test data.

11.3 Precision may be judged from Fig. 1 and Fig. 2, which are Weibull plots of the data obtained in test programs.
involving two greases and seven cooperators. Weibull parameters calculated for the data are summarized in Table 2.\textsuperscript{5}

TABLE 2 Precision—Summary of Weibull Parameters (Figs. 1 and 2)

<table>
<thead>
<tr>
<th></th>
<th>Grease A</th>
<th>Grease B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weibull Slope</td>
<td>4.91</td>
<td>3.02</td>
</tr>
<tr>
<td>90% confidence limits</td>
<td>3.88 to 6.24</td>
<td>2.26 to 4.10</td>
</tr>
<tr>
<td>$L_{10}$ life, h</td>
<td>108</td>
<td>170</td>
</tr>
<tr>
<td>90% confidence limits</td>
<td>89 to 117</td>
<td>112 to 204</td>
</tr>
<tr>
<td>90% confidence limits, as percent of $L_{10}$</td>
<td>82 to 108</td>
<td>66 to 120</td>
</tr>
<tr>
<td>$L_{50}$ life, h</td>
<td>153</td>
<td>296</td>
</tr>
</tbody>
</table>

11.4 The precision of the test may also be judged by considering Table 3, which summarizes the data obtained in the cooperative program.

TABLE 3 Precision—Summary of Cooperative Testing Program

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Range for Center 50% of Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grease A</td>
<td>151</td>
<td>130 to 180</td>
</tr>
<tr>
<td>Grease B</td>
<td>297</td>
<td>220 to 388</td>
</tr>
</tbody>
</table>

11.5 Because the life results obtained show appreciable scatter, replicate testing is essential when using this procedure.

11.6 Bias—The procedure in this test method for measuring grease life in small ball bearings has no bias because the value of grease life in small ball bearings is defined only in terms of the test method.

12. Keywords

12.1 lubricating grease; lubricating grease life; lubricating grease torque; running torque; small ball bearings

\textsuperscript{5} Further details may be found in an article by Lindeman, et al., NLGI Spokesman, Vol 34, No. 4, July 1975, pp. 126–134.
ANNEXES

(Mandatory Information)

A1. Apparatus

A1.1 Complete Tester

A1.1.1 The complete tester is shown in Fig. A1.1. It consists of a mechanical unit and an instrument cabinet with connecting cables.

A1.2 Mechanical Unit

A1.2.1 A side view of the mechanical unit with the heater box removed is shown in Fig. A1.2. A 3600-r/min motor, pivot mounted to the base plate, drives the ball-bearing-supported spindle at 12 000 r/min by means of a flat belt. To drive the spindle at 1 r/min, a gearhead motor with a manual clutch is mounted in line with the spindle. Three columns from the base support a glass-bonded-mica plate for mounting the spindle assembly.

A1.3 Heater Box

A1.3.1 To operate the test bearing at temperatures above ambient, a glass-bonded-mica box with four cartridge heaters is placed over the test bearing and the adjacent spindle bearing. A thermocouple in the heater box and its connected temperature controller maintain an environmental temperature such that the test-bearing outer-race will operate at test temperature for the grease.

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6 The Model R-4 Bearing Grease Torque Tester is manufactured by O. P. Schuman and Sons, Inc., County Line and Titus Road, Warrington, PA 18976.
FIG. A1.1 Model R-4 Bearing Grease Torque Tester

FIG. A1.2 Mechanical Unit with Heater Box Removed
A1.4 Spindle Assembly

A1.4.1 Fig. A1.3 is a cross-section drawing showing the spindle assembly with loading and torque-measuring devices. A1.4.2 The 12 000-r/min pulley and the inner race of the adjacent floating bearing are clamped against a shoulder on the spindle by the pulley nut. The spindle turns on two R-4 ball
bearings, the one near the slinger being locked in the spindle housing by a retaining ring against its outer race.

A1.4.3 A slinger is mounted on the spindle next to the test bearing to circulate air and reduce temperature gradients inside the heater box.

A1.4.4 The test bearing is pushed into its rectangular housing and its outer race is clamped in place by the nose cone with four screws. The inner race of the test bearing, the slinger, and the inner race of the adjacent spindle bearing are all locked against a shoulder on the spindle by a nut prior to installing the nose cone.

A1.4.5 A hollow torque arm is screwed into the bottom of the test-bearing housing. It serves as an access for an iron-constantan, Type J thermocouple to the outer race of the test bearing, a means of applying radial load to the test bearing, and a displacement against the core of a transducer which is proportional to test-bearing torque.

A1.4.6 Loads for the test bearing are transmitted by bead chains. The axial chain from the nose cone to the curved cantilever provides a 5-lbf (22-N) axial load. The radial chain from the slotted nut at the bottom of the torque arm to the straight cantilever at the tester base provides a 1/2-lbf (2.2-N) radial load.

A1.4.7 Friction within the test bearing applies a torque to its housing when the inner race is rotated. An equal and opposite torque is applied to the housing by the torque arm due to radial-chain tension and the transducer-core cantilevers. For small displacement of the torque arm, about 1/32 in. (0.794 mm), the transducer output is proportional to bearing torque.

A1.4.8 Fig. A1.4 shows critical dimensions for parts of the spindle assembly.

A1.5 Calibration

A1.5.1 Calibration of the torque measuring instrumentation should be made with a hot tester after several hours of test-bearing operation.

A1.5.2 Remove the heater box and the drive belt.

A1.5.3 Vibrate the bead chains gently by tapping with a pencil. Then advance the torque table until the torque read-out meter indicates a slight up-scale deflection. Record this reading as meter-tare for zero torque.

A1.5.4 Mount calibration arm on top of test-bearing housing. It must be balanced with the weighthanger notch at 50 mm from the center of the test bearing.

A1.5.5 Add various weights in grams to the calibration arm and record meter readings. Gently vibrate chains for each reading.

A1.5.6 Plot a calibration curve of applied torque (gram-weight times 50 mm) versus net meter readings (meter reading for a given weight minus meter-tare).

A1.5.7 The calibration potentiometer can be used to change the slope of the calibration curve.

A1.6 Schematic Circuit

A1.6.1 A schematic power wiring diagram is shown in Fig. A1.5 (the numbers in parentheses in this section refer to Fig. A1.5).

A1.6.2 Power switch (1) connects the 110-V a-c power supply.

A1.6.3 Fuse (2) protects the circuitry and pilot (3) indicates that the circuitry is operational.

A1.6.4 Low-speed motor (1-r/min motor) (4) is manually turned on by low-speed motor switch (5).

A1.6.5 Meter relay (6) is the torque read-out indicator and incorporates an over-torque cut-off relay contact.

A1.6.6 Run-time meter (7) indicates total hours of operation and runs as long as start relay (9) remains closed.

A1.6.7 Momentary contact switch (8) energizes start relay (9) which will remain latched-in until power failure or opening of a safety contact. Safety contacts are over-torque (6), limit switch for belt break (11), and over-temperature at controller (17).
A1.6.8 Cycle timer (10) is powered by the upper contact of start relay (9). The contact in cycle timer (10) turns power relay (12) on for 20 h and off for 4 h.

A1.6.9 The lower contact of power relay (12) in series with manual high-speed motor switch (15) operates high-speed motor (14) for 12 000-r/min spindle speed. The upper contact of power relay (12), in series with manual heater switch (16), supplies power from variable transformer (13) to the contact of heater relay (18).

A1.6.10 If temperature controller (17) calls for heat in the heater box over the test bearing, its control contact energizes heater relay (18). The contact in heater relay (18) completes the power circuit to energize heaters (19).

A1.6.11 Run timer (7), cycle timer (10), power relay (12), high-speed motor (14), and heaters (19) all become de-energized by means of start relay (9) in case of power failure or safety signal. Momentary contact switch (8) must be manually pushed to put the tester back in operation.

A1.7 Precision Torque Measurement

A1.7.1 Since the torque arm is rigidly attached to the test-bearing housing and the outer race of the test bearing is clamped in this housing, the torque arm magnifies any run-out of the test bearing raceways. Turning the spindle to various positions may result in different meter-tare readings. Precisions torque measurements, especially at 1 r/min can be obtained as outlined below, provided the spindle is marked at 90-deg intervals, one through four.

A1.7.2 For 12 000-r/min Torque:
A1.7.2.1 Record the meter reading at 12 000 r/min with stabilized temperature.
A1.7.2.2 Stop the drive motor, remove the belt, and record the meter-tare at the four marked positions of the spindle.
A1.7.2.3 Average the meter-tare readings and subtract the mean value from the 12 000-r/min meter reading.
A1.7.2.4 From the calibration curve of torque in gram-centimetres versus net-meter readings, observe and record the 12 000-r/min torque in gram-centimetres.

A1.7.3 For 1-r/min Torque:
A1.7.3.1 Engage the 1-r/min motor clutch and turn on the 1-r/min gearhead motor.
A1.7.3.2 Record meter readings for each of the four marked positions of the spindle.
A1.7.3.3 Subtract the meter-tare for each spindle position from its corresponding meter reading to determine four values of net-meter reading at 1 r/min.
A1.7.3.4 Average these four net-meter readings to obtain a mean 1-r/min meter reading.
A1.7.3.5 From the calibration curve of torque in gram-centimetres versus net-meter readings, observe and record the 1-r/min torque.
A1.7.4 Stop the 1-r/min gearhead motor, disengage the 1-r/min clutch, replace the belt, and restart on high speed.

A2. TECHNIQUE FOR SCREENING GREASE

A2.1 Partially fill a clean 2-oz (56-g) or 4-oz (112-g) hand-type grease gun with the test grease.

A2.2 Pump the grease through a clean 40-µm (Sieve No. 325, U.S. Sieve Series) retention filter\(^7\) into a clean container which can be tightly covered. This filter should have a slot milled across its outlet for grease discharge. The inlet should be fitted with a standard grease fitting to match the hand-type grease gun.

A2.3 Place the cover on the container and label.

A2.4 When packing a bearing, keep the container covered as much as possible. Dust and lint in the air will contaminate the filtered grease sample.

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\(^{7}\) A suitable filter is No. FKW-X5-4PP with ¼-in. FNPT ends for 40-µm retention manufactured by Fluid Dynamics, 1750-T Memtec Dr., Deland, FL 32724-2045.
Standard Specification for Roof and Rock Bolts and Accessories

This standard is issued under the fixed designation F 432; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the chemical, mechanical, and dimensional requirements for roof and rock bolts and accessories. Addressed in this specification are double-end threaded and slotted steel bars; fully grouted bolts and threaded bars; mechanical anchorage devices used for point anchorage applications; roof truss systems; partially grouted deformed bolts; formable anchorage devices; and other frictional anchorage devices. All of these products represent various designs used for ground support systems. This specification can be revised to address new technologies.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 This hazard statement applies only to Section 10, Test Methods of this specification. This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
- A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for
- A 47 Specification for Ferritic Malleable Iron Castings
- A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service
- A 220 Specification for Pearlite Malleable Iron
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 536 Specification for Ductile Iron Castings

- A 563 Specification for Carbon and Alloy Steel Nuts
- A 568/A 568M Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for
- A 615 Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- D 1248 Specification for Polyethylene Plastics Molding and Extrusion Material
- F 436 Specification for Hardened Steel Washers
- F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

2.2 ASME Standards:
- B 1.1 Unified Screw Threads
- B 1.3M Screw Thread Gaging Systems for Dimensional Acceptability—Inch and Metric Screw Threads
- B 18.2.2 Square and Hex Nuts

3. Terminology

3.1 Definitions:

3.1.1 bearing plates, plate washers, mine roof plates—plates that serve to distribute the load from the exposed end of the bolt or threaded bar to the rock face or intermediate member.

3.1.1.1 header plates—large rectangular bearing plates, usually 6 in. (152 mm) wide by 16 to 18 in. (406.4 to 457.2 mm) long, or any other shape with an equivalent area, used in substitution for wooden header blocks for wider distribution of the bolt load than is possible with standard bearing plates.

3.1.2 bendable bolts—bolts furnished with an altered section at some location, to be specified by the customer, at which the bar will bend.

3.1.2.1 Discussion—Bending is necessary to permit installation of bars longer than the mine opening height. This altered section may be produced by hot or cold forging, or by shearing, sawing, trimming, machining, grinding, or a combination of these processes.
3.1.3 beveled washers—washers whose faces are at an angle permitting a headed bolt or threaded bar to be installed at a slight angle to the rock face and yet maintained the face of the bolt head perpendicular to the bolt axis.

3.1.4 chemical anchors—chemical materials that provide anchorage between the bolt or bar and the drilled hole.

3.1.5 expansion shells—anchorage devices that expand to grip the sides of a drilled hole mechanically and transfer load from the location of the anchor to the bar or bolt.

3.1.6 extensions—threaded bars used to extend the length of threaded or threaded slotted bars.

3.1.7 formable anchorage devices—any roof support devices that provide anchorage through some means of physical interference and engagement of the surface of a bar or bolt with any formable material, other than chemical grout, in a bore-hole.

3.1.8 frictional anchorage devices—roof support devices that are designed so that the holding force acts over the full contact length.

3.1.9 fully grouted bolts and threaded bars—deformed bars or plain bars used with full-length grouting and having special deformations or other design features to provide interlocking between the steel and the grout.

3.1.10 hardened washers—washers that have been hardened by heat treatment to provide consistency to the torque tension relation necessary to control installation tension of bolts and threaded bars.

3.1.11 minimum non-seizure load (MNSL)—the load level in pounds through which bolt/plug thread seizure must not occur.

3.1.12 minimum ultimate load (MUL)—the load level in pounds through which bolt/plug thread failure must not occur.

3.1.13 rollers, cams—moving devices that, when used with internally threaded cylinders containing external tapered slots, provide expansion to grip the sides of a drilled hole mechanically and transfer load from the location of the anchor to the bar or bolt.

3.1.14 roof and rock bolts—headed hot-rolled bars with cold-rolled or machine-cut threads at the other, into which a tapering wedge can be inserted. When each assembly is driven into a bottomed hole, the wedge spreads the slot and an anchorage is produced.

3.1.15 threaded tapered plugs—threaded wedge that expands the expansion shell by the movement of the threaded plug within the shell as tightening progresses.

4. Ordering Information

4.1 Orders for material under this specification shall include at least the following information:

4.1.1 Quantity (number of pieces),

4.1.2 Name of product together with description of accessories,

4.1.3 Dimensions,

4.1.4 ASTM designation and year of issue, including strength grade,

4.1.5 Special requirements, if any, including packaging and thread protection instructions, and

4.1.6 Certifications, if required.

4.2 The products covered by this specification are currently produced by many manufacturers to a wide variety of designs. It is necessary for the user and the manufacturer to establish the requirements of the individual installation and to agree as to the type of assembly to be employed. See Annex A1 and Appendix X1 for additional information.

5. Manufacturing Processes

5.1 Materials for Bolts, Extensions, and Threaded or Threaded Slotted Bars:

5.1.1 Steel shall conform to the requirements shown in Table 1 and in Specification A 29 for plain bars or Specification A 615 for plain or deformed bars unless otherwise specified.

5.1.1.1 Threaded slotted bars may have the slot produced by forging, burning, or sawing. Burned slots of Grades 55 and 75 threaded slotted bars must have the slotted end normalized by heating to a minimum of 1600°F (870°C) and air cooling subsequent to burning.

<table>
<thead>
<tr>
<th>TABLE 1 Chemical Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
</tr>
<tr>
<td>Bolts, threaded bars, and threaded slotted bars*</td>
</tr>
<tr>
<td>Steel tapered wedges</td>
</tr>
<tr>
<td>Hardened spherical, flat, or beveled washers</td>
</tr>
<tr>
<td>Spherical or beveled washers</td>
</tr>
<tr>
<td>Bearing and header plates</td>
</tr>
<tr>
<td>Steel threaded tapered plugs</td>
</tr>
<tr>
<td>Steel expansion shells</td>
</tr>
</tbody>
</table>

*Bars furnished in accordance with Specification A 615 may be substituted for these requirements.

aCheck analysis for sulfur if a resulfurized steel is not technically appropriate.

2
5.1.2 Threads on bolts or threaded bars may be cold rolled or machine cut on the hot-rolled bars.

5.2 Materials for Tapered Wedges for Use With Threaded Slotted Bars:

5.2.1 Malleable iron casting shall conform to Specification A 47.

5.2.2 Pearlite malleable iron castings shall conform to Specification A 220, Grades 45006 or 50005.

5.2.3 Steel shall conform to the requirements shown in Table 1.

5.3 Materials for Expansion Shells:

5.3.1 Malleable iron castings shall conform to Specification A 47.

5.3.2 Steel shall conform to the requirements shown in Table 1.

5.3.3 Ductile iron castings shall conform to Specification A 536, Grades 60-40-18.

5.4 Materials for threaded tapered plugs used with expansion shells shall conform to the test specifications in 10.8.

5.5 Materials for Bearing and Header Plates, Also Known As Plate Washers or Mine Roof Plates:

5.5.1 Steel shall conform to the requirements shown in Table 1.

5.5.1.1 Bearing and header plates may be strengthened by cold forming or may be hardened by quenching in a liquid medium from above the austenitizing temperature and tempering at a temperature of not less than 650°F (345°C).

5.6 Materials for Spherical, Flat, or Beveled Hardened Washers:

5.6.1 Steel shall conform to the requirements shown in Table 1.

5.6.1.1 Hardened steel washers shall be through hardened by quenching in a liquid medium from above the austenitizing temperature and tempering at a temperature of not less than 650°F (345°C). Case-hardened washers are not permitted.

5.7 Materials for Spherical or Beveled Washers:

5.7.1 Malleable iron castings shall conform to Specification A 47.

5.7.2 Pearlite malleable iron castings shall conform to Specification A 220, Grades 45006, 50005, or 60004.

5.7.3 Steel shall conform to the requirements shown in Table 1.

5.8 Nuts shall be in accordance with Specification A 194 or A 563. Appropriate nuts for each grade of threaded bar are shown in Table 2. Higher strength nuts conforming to Specifications A 194 or A 563 may be substituted. When specified on the order or contract, nuts with external dimensions of nominal ½-in. heavy hex or heavy square size may be supplied with ¾-in. threads for use with ½-in. threaded bars.

5.9 Chemical grouting materials are covered in Annex A3 of this specification.

5.10 Materials for threaded couplings shall be selected by the manufacturer to ensure compliance with 7.6 and 8.7.

5.11 Materials for Bolts and Threaded Bars for Use in Grouted Systems—Plain or deformed steel bars shall conform to Table 1 or Specification A 615.

5.12 Materials for Frictional Anchorage Devices—Sheet steel shall conform to Specification A 568/A 568M.

5.13 Components of roof truss systems shall be manufactured in accordance with the appropriate paragraph(s) of Section 5 of this specification.

5.14 Materials for Formable Anchors:

5.14.1 Materials for formable anchor tubes are as follows:

5.14.1.1 Polyethylene used for formable anchor tubes shall conform to ASTM D 1248 Classification Type III, Class A or B. Category 5.

Note: 1—All shapes, compositions, and properties of formable anchor materials are not covered by this specification. Users must ensure that the formable anchor material offered is suitable for its intended use.

6. Chemical Composition

6.1 Materials used for bolts, threaded bars, threaded slotted bars, spherical, flat, or beveled washers, threaded tapered plugs, tapered wedges, expansion shells, bearing plates and roof truss components shall be as specified in Table 1 and Section 5.

6.2 Materials for all cast or wrought metallic items other than those covered in 6.1 shall conform to the requirements as specified in Section 5.

6.3 Individual heats of steel or cast iron are not identified in any of the finished products.

6.4 Chemical analyses for steel products shall be performed in accordance with Test Methods A 751.

6.5 Materials for formable anchors shall conform to the requirements, if applicable, specified in Section 5.

6.6 Chemical analyses shall be performed in accordance with Test Methods A 751.

7. Mechanical Properties

7.1 Mechanical properties of steel bars, for the manufacture of bolts, threaded bars, or threaded slotted bars shall be as specified in Table 3 for the required grade.

7.2 Mechanical properties of steel bolts, threaded bars, and threaded slotted bars whose slots have been produced without

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**TABLE 2 Appropriate Nuts**

<table>
<thead>
<tr>
<th>Bolt, Threaded Bar, or Threaded Slotted Bar Grade</th>
<th>Nut Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 (regular strength)</td>
<td>A 194, Grade 1; A 563, Grade B</td>
</tr>
<tr>
<td>55 (high strength)</td>
<td>A 194, Grade 1; A 563, Grade B</td>
</tr>
<tr>
<td>75 (extra high strength)</td>
<td>A 194, Grade 2; A 563, Grade C</td>
</tr>
</tbody>
</table>

---

**TABLE 3 Mechanical Properties of Steel Bars for the Manufacture of Bolts, Threaded Bars, and Threaded Slotted Bars***

<table>
<thead>
<tr>
<th>Grade</th>
<th>Nominal Diameter, in.1</th>
<th>Yield Point min, psi (MPa)</th>
<th>Tensile Strength min. psi (MPa)</th>
<th>Elongation in 8 in. or 200 mm Minimum, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>5/8-1 1/8</td>
<td>40 000 (276)</td>
<td>70 000 (483)</td>
<td>12</td>
</tr>
<tr>
<td>55</td>
<td>5/8-1 1/8</td>
<td>55 000 (379)</td>
<td>85 000 (586)</td>
<td>12</td>
</tr>
<tr>
<td>60</td>
<td>5/8-1 1/8</td>
<td>60 000 (414)</td>
<td>90 000 (621)</td>
<td>9</td>
</tr>
<tr>
<td>75</td>
<td>5/8-1 1/8</td>
<td>75 000 (517)</td>
<td>100 000 (688)</td>
<td>8</td>
</tr>
<tr>
<td>100</td>
<td>5/8-1 1/8</td>
<td>100 000 (689)</td>
<td>125 000 (825)</td>
<td>6</td>
</tr>
</tbody>
</table>

---

*1 Test of bars shall be performed full size.
2 Higher grades would be produced in 20 000-psi increments. The minimum tensile strength shall be 25 000 psi above the minimum yield strength. The minimum elongation shall be 4 % for all grades above 100.
3 Actual bar diameters are somewhat less than nominal, especially when roll threading methods are employed.
4 Grade 40 and 60 only apply to deformed bar.
material removal shall be as specified in Table 4 for the required grade.

7.3 Expansion shells, threaded tapered plugs, tapered wedges, and spherical washers shall conform to the applicable specification of Section 5 and shall successfully perform the required purpose as described in Annex A1.

7.4 Bearing plates and header plates that are strengthened by quenching and tempering shall have a maximum hardness of 45 HRC.

7.4.1 Bearing plates and header plates shall be provided in 10 000-lbf (44.5-kN) grade increments. The minimum grade rating permitted shall be 20 000 lbf (89.0 kN).

7.5 Hardened washers shall have a hardness range from 35 to 45 HRC.

7.6 Threaded couplings must be capable of developing the actual yield and tensile values of the bolt, threaded bar, or threaded slotted bar with which they are to be used.

7.7 Extensions must be in accordance with 7.1 and 7.2 for the grade of item specified.

7.8 Mechanical properties for bolts and threaded bars for use in grouted systems shall be as specified in Table 3 for plain bars; and Table 3 or Specification A 615 for deformed bars. Bolts and threaded bars made from plain material must contain some design feature to provide interlocking between the steel and the grout. These items can be supplied threaded or headed.

7.9 Threaded slotted bars whose slots have been produced by burning shall be heat treated by normalizing in accordance with 5.1.1. The normalizing heat treatment and the removal of material from the slot, whether it be by burning or sawing, will result in lower test values. When either the burning or sawing or other methods involving metal removal are used, the mechanical properties of threaded slotted bolts shall be as specified in Table 5.

7.10 Threaded tapered plugs for expansion anchors must be capable of withstanding the minimum nonseizure load (MNSL) and minimum ultimate load (MUL), in accordance with Table 6.

7.11 Tension nuts must be capable of withstanding the ultimate tensile strength of the bolt or rebar of the highest grade with which they are to be used.

7.12 The mechanical properties of components of roof truss systems shall be in accordance with the appropriate paragraph(s) of this section.

7.12.1 Truss brackets shall be provided in 10 000-lbf (44.5-kN) grade increments.

7.13 Formable anchor materials shall conform to the applicable specifications of Section 5.

8. Dimensions, Mass, and Permissible Variations

8.1 Threaded bolts shall conform to the dimensions shown in Fig. 1.

8.1.1 Deformed bar bolts are bars that have been forged to produce one of the standard heads described in Fig. 1.

8.2 Threaded and threaded slotted bars shall conform to the

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### TABLE 4 Load Support Requirements of Steel Bolts, Threaded Bars, (see Annex A2) Threaded Deformed Bars, and Threaded Slotted Bars Whose Slot Has Been Produced Without Metal Removal

<table>
<thead>
<tr>
<th>Nominal Diameter (in.)/Thread</th>
<th>Grade</th>
<th>40°</th>
<th>55</th>
<th>60°</th>
<th>75</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>in.</td>
<td></td>
<td>in.²</td>
<td>kN</td>
<td>m²</td>
<td>kN</td>
<td>kN</td>
</tr>
<tr>
<td>¼–11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.226</td>
<td>⁶ ⁶</td>
<td>⁶ ⁶</td>
<td>2400</td>
<td>⁶ ⁶</td>
<td>⁶ ⁶</td>
<td>⁶ ⁶</td>
</tr>
<tr>
<td>1/8</td>
<td>⁶ ⁶</td>
<td>⁶ ⁶</td>
<td>2400</td>
<td>⁶ ⁶</td>
<td>⁶ ⁶</td>
<td>⁶ ⁶</td>
</tr>
<tr>
<td>0.668</td>
<td>⁶ ⁶</td>
<td>⁶ ⁶</td>
<td>2400</td>
<td>⁶ ⁶</td>
<td>⁶ ⁶</td>
<td>⁶ ⁶</td>
</tr>
<tr>
<td>0.969</td>
<td>⁶ ⁶</td>
<td>⁶ ⁶</td>
<td>2400</td>
<td>⁶ ⁶</td>
<td>⁶ ⁶</td>
<td>⁶ ⁶</td>
</tr>
</tbody>
</table>

---

**Note:** Tests of bolts and threaded bars shall be performed using full-diameter products.

---

**Note:** Information for Gr 40 and 60 only applies to deformed bars.

---

**Note:** Required yield and tensile loads shown are calculated by multiplying thread stress areas times the yield point and tensile strength values shown in Table 3. Thread stress area is calculated from the mean root and pitch diameters of adrenal threads as follows:

\[ A_s = 0.7854 \left( \frac{D}{n} \right)^2 \]

where:

- \( A_s \) = stress area, in.²
- \( D \) = nominal diameter, in., and
- \( n \) = number of threads per inch.

---

### Footnotes:

1. In. Gr 40 products are not covered.
TABLE 5 Load Support Requirements for Threaded Slotted Bars Whose Slot Has Been Produced by Methods Involving Metal Removal

<table>
<thead>
<tr>
<th>Nominal Diameter, in.</th>
<th>Thread Stress Area, min. in.$^2 (\text{mm}^2)$</th>
<th>Grade 55</th>
<th>Yield Load, min. lbf (kN)$^d$</th>
<th>Ultimate Tensile Load, min. lbf (kN)$^d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.155 (7.45)</td>
<td>57</td>
<td>200 (254.2)</td>
<td>88 (393.1)</td>
</tr>
<tr>
<td>1¼</td>
<td>0.969 (6.25)</td>
<td>48</td>
<td>193 (213.4)</td>
<td>74 (329.9)</td>
</tr>
<tr>
<td>1½</td>
<td>1.155 (7.45)</td>
<td>57</td>
<td>200 (254.2)</td>
<td>88 (393.1)</td>
</tr>
<tr>
<td>1⅜</td>
<td>1.405 (9.06)</td>
<td>69</td>
<td>600 (309.4)</td>
<td>107 (478.0)</td>
</tr>
</tbody>
</table>

$^a$Tests of bolts, threaded bars, and threaded slotted bars shall be performed using full-diameter products.

$^d$Required yield and tensile loads shown are calculated by multiplying thread stress areas times the yield point and tensile strength values shown in Table 2.

Thread stress area is calculated from the mean of the mean root and pitch stress areas times the yield point and tensile strength values shown in Table 2.

8.3 Thread Requirements:

NOTE 2—Thread size variations can be expected due to bar diameter and out-of-round variations. These special requirements reflect practices for external and internal threads that have been found to provide adequate strength and interchangeability.

8.3.1 External threads shall be in accordance with ASME B 1.1 UNC 1B except that the threads shall be tapped oversize. This oversize is an increase in the pitch diameter of 0.003 in. (0.08 mm) to allow for handling damage on the external thread and dirt and long engagement in the internal thread. The maximum minor diameters are standard 1B for 1½ to 3 diameter length of engagement. The modified requirements are listed in Table 7.

8.3.2 Internal threads in threaded tapered plugs and threaded couplings shall be in accordance with ASME B 1.1 UNC 1B except that the threads shall be tapped oversize. This oversize is an increase in the pitch diameter of 0.003 in. (0.08 mm) to allow for handling damage on the external thread and dirt and long engagement in the internal thread. The maximum minor diameters are standard 1B for 1½ to 3 diameter length of engagement. The modified requirements are listed in Table 7.

8.3.3 Internal threads in nuts shall be tapped standard UNC 2B size in accordance with ASME .1 or may be tapped oversize in accordance with 8.3.2 with agreement of producer and purchaser.

8.3.4 Gaging of threads shall be performed in accordance with System 21, ASME B 1.3M. Pitch diameter and thread crest diameter limits are specified in Table 7.

8.3.5 Threaded tapered plugs shall have a tapped length at least equal to one times the nominal bolt diameter with which they are to be used.

8.3.6 Threaded couplings shall have a tapped length at least equal to two times the nominal bolt diameter with which they are to be used.

8.4 Round and square hardened washers shall be as shown in Fig. 3.

8.4.1 There are two types of hardened flat washers available. Type 1 is to be furnished unless otherwise specified.

8.4.1.1 Type 1 is either circular or square as shown in Fig. 3. It is designed for use with plate washers containing 1½-in. (35-mm) holes, but may be used for all smaller hole sizes.

8.4.1.2 Type 2 is the hardened flat washer in accordance with Specification F 436. It may be used only when sufficient clearance is available between the threaded-bar or threaded-rolled-bar body diameter near the head and the washer hole. This washer is not suitable for use with plate washers that contain holes that are more than ⅜ in. (9.5 mm) greater in diameter than the nominal bolt diameter.

8.5 Bearing and header plates may be of any thickness that successfully meets the test requirements in accordance with 10.4. The maximum hole size for use with bolts up to 3/4-in. nominal diameter shall be 1½ in. (35 mm) except that hole size may be 1½ in. (38 mm) when spherical washers or seats are used. Tolerance on hole diameter shall be −0, ⅛ in. (−0, +3.2 mm). Bearing plates for direct bearing applications shall be 6 in. (152 mm) wide by 16 to 18 in. (406.4 to 457.2 mm) long, or any other shape with an equivalent area.

8.6 Bearing and header plates used with frictional anchorage devices shall meet the test requirements in 10.4. The hole sizes and tolerances shall be set by the manufacturer of the frictional anchorage device.

8.7 Dimensions not otherwise specified for tapered wedges, expansion shells, threaded tapered plugs, beveled washers, spherical washers, threaded couplings, and extensions shall be...
by agreement between the producer and the purchaser.

8.8 Nuts shall be hex, heavy hex, square, or heavy square in accordance with ASME B 18.2.2. Unless otherwise specified, the heavy series shall be supplied.

8.9 Surface Configuration on Formable Anchor Bars or Bolts:

8.9.1 Surface configurations on steel bars or bolts to be used with polyethylenes, as specified in 5.14.1.1, formable anchorage devices.

8.9.1.1 Three pitch modified reverse buttress form as described in Fig. 4.

8.10 Dimensions of Formable Anchor Tubes:

Note 1—Pinched ears may be provided to support the expansion shell during installation.

Note 2—See 8.3.1 for threads.

Note 3—E Body diameter is established by the method of threading.

Note 4—Body diameter is controlled by the roll threading operation.
8.10.1 Dimensions of formable anchor tubes made from materials conforming to 5.14.1.

8.10.1.1 The wall thickness of the formable anchor tube shall be as specified by the manufacturer, 0.015 in.

8.10.1.2 The weight per inch of formable anchor tubes shall be as specified by the manufacturer, 8%.

8.10.1.3 The length of formable anchor tubes shall be as specified by the manufacturer, 0.250 in.

NOTE 4—Barrier plugs may be used with the formable anchor tubes to separate grouted or chemically anchored segments of the bars or bolts from formable anchorage devices. In such cases, the barrier plug shall be considered as a portion of the tube length.

9. Number of Tests and Retests

9.1 Bars—Two tension tests shall be made from each heat for each nominal diameter of bars unless the finished material from a heat is less than 30 tons (27.2 Mg), when one tension test will be sufficient. Certification by the bar supplier that the requirements of Table 3 have been met is an acceptable substitute for these bar tension tests.

9.2 Bolts, Threaded Bars, Threaded Slotted Bars, Bearing and Header Plates, and All Types of Washers—The requirements of this specification shall be met in continuous mass production. The manufacturer shall make sample inspections and tests to ensure that the product represented by the test samples conforms to the specified requirements. The manufacturer shall select and test a minimum of two bolts, threaded bars, threaded slotted bars, bearing and header plates, and washers from each discontinuous turn or each 24 h of continuous production.

9.3 Improper machining or preparation of test specimens may give erroneous results. Improperly machined specimens shall be discarded and other specimens substituted.

9.4 If any test specimen fails to meet the specification requirements because of failure of testing equipment or improper specimen preparation, it may be discarded and another specimen taken.

10. Test Methods

10.1 Test bars used for the manufacture of bolts and threaded and threaded slotted bars for yield point, tensile strength, and elongation in accordance with the Determination of Tensile Properties Section of Test Methods A 370.

10.2 Tension test bolts and threaded bars in accordance with the Wedge Tension Testing of Full Size Product paragraph of
Testing of Machined Test Specimens of Test Methods F 606.

10.2.1 If the length of the bolt or threaded bar exceeds the length that can be accommodated by the testing machine, then cut the head with a portion of the body in the case of bolts, and the thread with a portion of the body, from the bolt or threaded bar and test each separately.

10.2.1.1 Test the section containing the threads for yield point and breaking load by using the nut intended for use on the threaded portion and by gripping the bolt body. Failure may not occur by stripping of threads.

10.2.1.2 Test the section containing the bolt head with a 10° wedge under the head and by gripping the body. For smooth bars, it is permissible to increase the hole clearance in the wedge plate to 2 times the clearance specified in Test Methods F 606 to accommodate collars or swell under the bolt head. For deformed bars, it is permissible to increase the hole clearance of the wedge plate to 4 times the clearance specified in Test Methods F 606.

10.2.1.3 Test bolts containing surface configurations by gripping a section of the surface configuration and the body of the bolt.

10.3 Threaded Slotted Bars:

10.3.1 Threaded slotted bars from which material has not been removed during the slotting operation (forged split-end bars) need not be tested on the slotted end.

10.3.2 Threaded slotted bars from which material has been removed when making the slot at the slotted ends. If the length of the bar exceeds the length that can be accommodated by the testing machine, then the excess length may be cut off and discarded.

10.3.2.1 Perform the test of the slotted end by first tack welding the two sides together at the extreme end of the bar.

10.4 Tests of Bearing and Header Plates:

10.4.1 Locate the bearing plate sample centrally on a steel test plate containing a hole 4 in. (102 mm) in diameter. The steel test plate shall be the dimensions shown in Fig. 4. Exert a load on the bearing plate by either (1) assembling bolt, threaded rod and nut, or fixture through the bearing plate, placing the plate assembly on the crosshead of a testing machine and gripping the bolt, rod, or fixture and pulling down with the upper platen, or (2) pushing down with a punch having a diameter of approximately 1.75 in. (45 mm) or equal to the fixture’s outside diameter, whichever is greater, mounted underneath the upper platen onto the plate assembly placed on the lower platen of the testing machine. If it is to be included in the actual installation, include in the test assembly a hardened washer of the type defined in this specification. Apply an initial preload of 6000 lbf (26.7 kN) and then place a measuring device accurate to 0.001 in. (0.03 mm) so as to be capable of measuring the axial movement of the bolt head or ram. Set the measuring device to zero after application of the 6000-lbf preload. Increase the load to 15 000 lbf (66.7 kN) and read the axial movement, defined as deflection, from the measuring device. The maximum permissible deflection between the 6000 and 15 000-lbf loads is 0.120 in. (3.05 mm). Continue the application of load until the grade rating of the plate is reached and again read the axial movement from the measuring device. The maximum permissible deflection between 6000 lbf and the grade rating is 0.250 in. (6.35 mm).

10.4.2 Locate the plate sample centrally on a steel test plate containing a clear span of 6 in. (152 mm). The steel test plate shall be the dimensions shown in Fig. 5 and Fig. 6. Exert a load on the plate by either (1) assembling bolt, threaded rod and nut, or fixture through the plate, placing the plate assembly on the crosshead of a testing machine and gripping the bolt, rod, or fixture and pulling down with the upper platen, or (2) pushing down with a punch having a diameter of approximately 1.75 in. (45 mm) or equal to the fixture’s outside diameter, whichever is greater, mounted underneath the upper platen of the testing machine. If it is to be included in the actual installation, include in the test assembly a hardened washer of the type defined in this specification. Apply an initial preload of 6000 lbf (26.7 kN) and then place a measuring device accurate to 0.001 in. (0.03 mm) so as to be capable of measuring the axial movement of the bolt head or ram. Set the measuring device to zero after application of the 6000-lbf preload. Increase the load to 15 000 lbf (66.7 kN) and read the axial movement, defined as deflection, from the measuring device. The maximum permissible deflection between the 6000 and 15 000-lbf loads is 0.120 in. (3.05 mm). Continue the application of load until the grade rating of the plate is reached and again read the axial movement from the measuring device. The maximum permissible deflection between 6000 lbf and the grade rating is 0.250 in. (6.35 mm).

10.4.2.1 Locate the plate sample centrally on a steel test plate containing a clear span of 6 in. (152 mm). The steel test plate shall be the dimensions shown in Fig. 5 and Fig. 6. Exert a load on the plate by either (1) assembling bolt, threaded rod and nut, or fixture through the plate, placing the plate assembly on the crosshead of a testing machine and gripping the bolt, rod, or fixture and pulling down with the upper platen, or (2) pushing down with a punch having a diameter of approximately 1.75 in. (45 mm) or equal to the fixture’s outside diameter, whichever is greater, mounted underneath the upper platen of the testing machine. If it is to be included in the actual installation, include in the test assembly a hardened washer of the type defined in this specification. Apply an initial preload of 6000 lbf (26.7 kN) and then place a measuring device accurate to 0.001 in. (0.03 mm) so as to be capable of measuring the axial movement of the bolt head or ram. Set the measuring device to zero after application of the 6000-lbf preload. Increase the load to 15 000 lbf (66.7 kN) and read the axial movement, defined as deflection, from the measuring device. The maximum permissible deflection between the 6000 and 15 000-lbf loads is 0.120 in. (3.05 mm). Continue the application of load until the grade rating of the plate is reached and again read the axial movement from the measuring device. The maximum permissible deflection between 6000 lbf and the grade rating is 0.250 in. (6.35 mm).

Grip both ends of this test bar and contain at least 1 in. (25 mm) of slot in the tested portion between the grips.
10.5 Perform hardness tests of washers and bearing and header plates in accordance with Test Methods F 606.

10.6 Tests of wedges for use with slotted bolts are not ordinarily contemplated.

10.7 Expansion shells and threaded tapered plugs shall be tested by the manufacturer in accordance with the specification to which they are supplied.

10.8 This test is to determine the grade rating specified in Table 6 for threaded tapered plugs used in expansion anchors. This test is not considered to be a routine test to be performed during manufacture, but must be applied in cases where the strength and performance of the threaded tapered plug have become an issue. This test can be executed in a variety of ways, all of which must include installation of the bolt, expansion shell, and threaded tapered plug in a straight section smooth hole of a diameter recommended by the manufacturer ± 0.030 in. The test cylinder or block shall be fabricated to dimensions that will allow the expansion anchor to be completely inserted into the hole and prevent lateral distortion of the hole during testing. The test shall be performed by tightening the assembly in the hole and then loading to the minimum nonseizure (MNSL) load for the grade of plug specified in Table 6. This loading after the initial setting shall be either by axial loading or by the turning of the bolt. The assembly shall then be removed from the test cylinder or block and examined. Following an initial full turn (with a wrench, if necessary), the plug must be removable by a torque load not to exceed 10 ft/lb. The threaded tapered plug shall not have ruptured nor the threads stripped. Threaded tapered plugs for expansion shells must also be capable of withstanding the minimum ultimate load (MUL) for the grade of plug specified in Table 6. This test shall be conducted by repeating the previous procedure and loading the assembly to the MUL. The assembly then shall be removed and examined. No stripping of the plug threads shall have occurred. At the MUL, distortion of the plug or bolt threads, or both, may preclude the removal of the plug.

Note 6—When threaded tapered plugs for expansion shells are used in conjunction with chemical grouting materials, the provisions of 7.10 also are applicable.

10.9 See Annex A1 for information concerning performance tests of expansion shell, tapered plugs, tapered wedges, and other anchorage methods and materials.

10.10 Nuts shall be manufactured and tested in accordance with the specification to which they are supplied, except that when so specified on the order or contract nuts of tapped sizes 5⁄8 and 3⁄4 in. may be the same 1 1⁄8-in. (28.58-mm) dimension across flats as the head of the bolt shown in Fig. 1.

10.11 Tension nuts must be capable of withstanding the ultimate tensile load capacity of the bolt or rebar of the highest grade with which they are to be used. This test is not considered to be a routine test to be performed during manufacturing, but must be applied in cases where the strength and performance of the threaded tension nuts have become an issue. This test may be carried out by engaging the threaded tension nut with the bolt or rebar, supporting the tension nut and then loading to the ultimate tensile strength (to destruction) of the highest grade bolt or rebar to be used. The assembly shall then be removed and examined. The threaded tension nuts shall not have ruptured nor the threads be stripped. At ultimate tensile loads, distortion of the bolt threads as well as elongation of the bolt in the engaged thread zone may preclude the
10.12 Tests of Notched Bendable Bolts:
10.12.1 Notched bendable bolts shall be capable of being bent through one bending cycle as follows: the bend shall be in the area of the reduced cross section, to an angle of 90°, with respect to its original position. The bar at the reduced section shall neither be guided nor restrained during the test. The bolt shall then be bent in the same manner back to its original position. At the conclusion of the bend test, any obvious visible evidence of cracking shall constitute reason for rejection.

10.12.2 Bolts successfully passing the bend test shall be tension tested with the bendable section in the zone of the tension test. Fully grouted nontensioned bendable bolts shall have reached a load of 23,000 lbf (102 kN) before breaking. Tensioned bendable bolts shall exceed the minimum yield loads in accordance with Specification A 615 or this specification, or both, for the grade and diameter of bolt used, plus 6000 lbf. There should be no evidence in the fracture of a prior fracture as a result of the bending test.

10.13 Tests of Roof Truss Components:
10.13.1 All components of roof truss systems shall be tested in accordance with the appropriate paragraph of Section 10 of this specification.
10.13.2 Truss brackets shall be tested to failure on a steel fixture in a position consistent with their intended use. Active loads shall be applied to the truss bracket through (1) the angle bolt while the horizontal member is held stationary, and through (2) the horizontal member while the angle bolt is held stationary. The bracket rating shall correspond to the lowest failure load determined by the tests described here.
10.13.2.1 Truss brackets used as primary support shall be tested as intended to be used over a 4-in. round hole at an appropriate angle to ensure that the bracket meets the minimum strength requirements of 10.4.

11. Quality Assurance and Inspection
11.1 If the inspection described in 11.2 is required by the purchaser, it shall be specified in the inquiry and in the contract or order.
11.2 Manufacturers of roof and rock bolts and accessories shall be responsible for establishing and maintaining a quality assurance program to ensure that all materials conform to the appropriate requirements of this specification. The manufacturer shall afford the purchaser’s inspector all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with this specification.

NOTE 1—A 36 or similar steel.
NOTE 2—Slot to be centrally located.
NOTE 3—Dimensions A and B shall each be a minimum of 2 in. (50.8 mm) longer than the comparable dimensions of the bearing or header plates to be tested.

FIG. 6 Span Test Plate
Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspection shall be made at the place of manufacture, unless agreed otherwise.

12. Rejection and Rehearing

12.1 Material that fails to conform to the requirements of this specification shall be rejected. Rejection shall be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

13. Certification

13.1 Upon request of the purchaser in the contract or order, a manufacturer's certification shall be furnished that the material was manufactured and tested in accordance with this specification.

14. Responsibility

14.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

15. Product Marking

15.1 Bolt heads shall be marked as shown in Table 8 with either raised or depressed marks at the option of the manufacturer. Marks shall include grade and diameter identification when applicable, manufacturer's symbol, and the bolt length in either inches or feet (or millimetres) as specified in the order or contract.

15.2 Frictional anchorage devices shall be marked with either raised or depressed marks at the option of the manufacturer. The location of the marks shall be such as to be readable after installation. Marks shall include model identification when applicable, manufacturer's symbol, and the length in either inches or feet (or millimetres) as specified in the order or contract.

15.3 Threaded bars and threaded slotted bars shall be color coded as shown in Table 9 to indicate bar length. The color shall be applied such that it will be visible for inspection after installation of the roof support device.

15.4 Beveled washers, threaded tapered plugs, wedges, spherical washers, and threaded couplings are not required to be marked.

15.4.1 Threaded tapered plugs produced in only one grade, as specified in Table 6, require no special identification if the plugs are uniquely identified by thread diameter and plug design. A plug having the same thread size and manufactured to more than one grade rating shall be identified by color coding or physical marking as specified by the manufacturer.

15.5 Deformed bearing and header plates shall be marked on the exposed face with the manufacturer's symbol.

15.6 Bearing and Header Plates:

15.6.1 Bearing and header plates manufactured to the minimum grade rating in accordance with 7.4.1 do not require markings to indicate grade rating.

15.6.2 Bearing and header plates manufactured to a grade rating higher than 20,000 lbf (89.0 kN) shall be marked with a single number that indicates the rating divided by 10,000 lbf (44.5 kN). For example, the number 3 would designate a 30,000-lbf (133.5-kN) grade rating.

15.7 Nuts shall be marked in accordance with the specification to which they were manufactured.

15.8 Expansion shells shall be marked with the manufacturer’s symbol and the hole size for which they are intended.

15.9 Each hardened washer shall be marked with a symbol identifying the manufacturer. Random washers may contain multiple markings. Markings shall be depressed on one face of the washer.

15.9.1 Other identifying or distinguishing marks, or both, may be used by the manufacturer.

15.10 Extensions are not required to be marked.

### TABLE 8 Markings\(^{A,B}\)

<table>
<thead>
<tr>
<th>Nominal Product Size, in.</th>
<th>Manufacturer's Symbol(^C)</th>
<th>Diameter(^D)</th>
<th>Grade(^E)</th>
<th>Length in Inches (or Millimetres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GR 40(^f)</td>
<td>¼-inch diameter and over</td>
<td>yes</td>
<td>yes</td>
<td>none</td>
</tr>
<tr>
<td>GR 55</td>
<td>½-inch diameter and over</td>
<td>yes</td>
<td>yes</td>
<td>★</td>
</tr>
<tr>
<td>GR 60(^f)</td>
<td>½-inch diameter and over</td>
<td>yes</td>
<td>yes</td>
<td>Δ</td>
</tr>
<tr>
<td>GR 75</td>
<td>½-inch diameter and over</td>
<td>yes</td>
<td>yes</td>
<td>¥</td>
</tr>
<tr>
<td>GR 100</td>
<td>½-inch diameter</td>
<td>yes</td>
<td>yes</td>
<td>□</td>
</tr>
</tbody>
</table>

\(^{A}\) No marks are required on beveled washers, threaded couplings, or extensions.

\(^{B}\) Other markings may be used to designate additional specifications and will be defined in the manufacturer’s literature.

\(^{C}\) Enter alpha numerical symbol.

\(^{D}\) Enter numerical value of bolt or bar diameter measured in eighths, for example, 5. Numerical value of deformed bars to be placed in a circle, for example ©.

\(^{E}\) Grades greater than 100 psi are to be produced in 20,000-psi increments and marked as follows, © for 120 psi, © for 140, etc.

\(^{F}\) Grade 40 and 60 only apply to deformed bar.

### TABLE 9 Color Codes for Threaded Bar and Threaded Slotted Bars

<table>
<thead>
<tr>
<th>Length, in. (ft., mm)</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>Purple</td>
</tr>
<tr>
<td>36</td>
<td>Yellow</td>
</tr>
<tr>
<td>42</td>
<td>Green</td>
</tr>
<tr>
<td>48</td>
<td>No Color</td>
</tr>
<tr>
<td>60</td>
<td>Red</td>
</tr>
<tr>
<td>72</td>
<td>Blue</td>
</tr>
<tr>
<td>84</td>
<td>Orange</td>
</tr>
<tr>
<td>96</td>
<td>White</td>
</tr>
</tbody>
</table>
15.11 Truss brackets shall be marked as shown in Table 8. Markings shall include the manufacturer’s symbol and the grade rating as determined by the test in accordance with 10.13.2. The grade identification shall consist of a single number that indicates the grade rating divided by 10,000 lbf (44.5 kN). For example, the number 3 would designate a 30,000-lbf (133.5-kN) grade rating.

15.12 Formable anchor tube container will be marked with nominal formable anchor tube length, bar or bolt diameter, wall thickness, weight per inch, and hole diameter with which tube is to be used.

15.12.1 Color coding of formable anchor tubes for mines using more than one bar or bolt diameter shall be established by the manufacturer.

ANNEXES

(Mandatory Information)

A1. ON-SITE TESTING TO DETERMINE EFFECTIVENESS OF ROOF SUPPORT DEVICES

A1.1 The suitability of roof and rock bolts and accessories for specific applications in underground mines depends upon the particular ground and rock conditions at the site of intended use. For this reason, it may be necessary to perform appropriate tests at the actual site of intended use to evaluate the effectiveness of the roof support devices.

A1.2 By agreement, the supplier and the purchaser will determine the appropriate tests to evaluate the merits of any specific roof support device on site.

A2. THREAD DEFORMED BARS

A2.1 Thread deformed bars are steel bars that have a continuous hot-rolled pattern of threadlike deformations along their entire length that allow nuts and couplers to thread onto the bar at any point.

A2.2 Thread deformed bars shall be manufactured in compliance with the chemical and mechanical property requirements of Specification A 615, Grade 60.

A2.3 Thread deformed bars shall be identifiable in regard to their manufacturer.

NOTE A2.1—Due to the manufacturing process, markings to designate size, minimum yield, and type of steel are not required.

A2.4 The effective stress area of thread deformed bars shall be equal to the nominal area of the bar.

A2.5 The dimensions of the threadlike deformations along the bar shall be adequate to develop, when engaged with a tension nut or coupler of the designated size, the ultimate strength of the thread deformed bar.

A2.6 Tension nuts for use with thread deformed bars shall have internal threads of sufficient strength to develop the ultimate tensile strength of the bar with which they are used. These nuts shall be marked with the letter T.

A2.7 Yieldable nuts for use with thread deformed bars shall be designed to yield in incremental displacements along the bars at predetermined bolt loads to allow for rock deformations under controlled support conditions.

A2.7.1 Standard yieldable anchor nuts shall develop at least 125% of the specified minimum yield strength of the bars with which they are used. No strength identification marking is required.

A2.7.2 Yieldable slip nuts designed to slip at loads less than 125% of the specified minimum yield are permitted. This percentage shall be marked on the nut.

A2.8 Couplings used with thread deformed bars shall conform to 7.6.

A2.9 Test methods and markings for thread deformed bars shall be consistent with the intended use of the bars in accordance with the appropriate sections of this specification.
A3. CHEMICAL GROUTING MATERIALS

A3.1 Strength Index for Chemical Grouting Materials

A3.1.1 This is a laboratory test for measuring the strength index of 6-in. long chemical anchors. The strength index is a numerical designation ranging from 1 to 10 that represents the load in tons that can be supported by a chemical anchor with less than 0.100 in. of bar movement when tested as outlined in this section. It is not intended to reflect actual in-mine performance or replace appropriate mine tests in accordance with A1.1.

A3.1.2 Prepare the test section as shown in Fig. A3.1. Item No. 1 is a No. 6 thread-deformed, reinforcing bar as described in Annex A2. Item No. 2 is a 1-in. inside diameter (I.D.) by 1½-in. outside diameter (O.D.) steel tube with 27 by 3 internal metric thread. Item No. 3 is a fully grouted, void-free, cured chemical anchor.

**Note A3.1**—It is required that the test section be cut from a large sample using a threaded tube length of at least 9 in. and a grout cartridge clipped at both ends. The length of thread-deformed bar used must be sufficient to allow attachment of the loading apparatus (see Fig. A3.1) to the protruding end. Care should be taken to ensure that the test section is completely grouted and void free throughout.

A3.1.3 Preparation of Test Section

Degrease tube and bar. Stabilize all components at a single temperature between 50 and 80°F. The specimen shall be prepared by placing the grout cartridge into the threaded tube, inserting the bar and rotating the bar clockwise in accordance with the chemical grout manufacturer’s installation instructions. The specimen shall be cured for 24 h before cutting the test section.

A3.1.4 Test Apparatus

Hydraulic ram with hollow center large enough to accept bar, manual hydraulic pump with a connecting hose and gage, and a dial indicator that measures movement to one thousandth of an inch.

A3.1.5 Test Procedure

As shown in Fig. A3.1, assemble the test section into the fixture and hydraulic ram. Attach the dial indicator to the steel tube to indicate movement of the cut end of the bar with respect to the tube.

A3.1.6 Manually apply load to the test section with the hydraulic ram in increments of 1 to 10-tons maximum load. Each increment of load shall be stabilized for a period of 1 min prior to reading the dial indicator. If movement exceeds 0.100 in., terminate the test.

**Note A3.2**—Do not exceed 10 tons due to bolt stretch and safety considerations.

A3.1.7 Number of Tests

A minimum of five tests are required. Eighty percent must achieve the strength index.

A3.2 Speed Index

A3.2.1 This is a laboratory test to determine the speed index of chemical grouting materials. The speed index indicates the time in seconds from completion of mixing until an anchorage level of 4000 lb is achieved when tested in accordance with this section. Grout formulations shall be identified in accordance with the speed index classification system of Table A3.1.

**Note A3.3**—Mine and installation conditions such as temperatures, annulus size, bolt length, and rotational speeds will effect results.

A3.2.1.1 Test apparatus is illustrated in Fig. A3.2. Degrease steel tube and bar before using. Stabilize all components at 55 to 60°F. Thread steel tube onto the base plate stud and position the steel support collar over the steel tube. Place the hollow core hydraulic ram on top of the steel support collar. Thread the No. 6 hex nut and the headed blind nut onto the thread deformed reinforcing bar so that the two nuts are locked.

**Note A3.4**—The thread deformed reinforcing bar must be long enough to ensure a 12-in. (±½, −0) grouted length.

A3.2.1.2 Place a sample of grout of sufficient volume to encapsulate a 12-in. (±½, −0) long section of No. 6 thread deformed reinforcing bar into the steel tube. Insert the bar (with nuts attached) through the grout in 5 s or less (rotating through the grout is optional). Immediately spin the bar clockwise at a speed between 400 and 500 r/min to mix the grout for the time recommended by the manufacturer. Begin timing for speed index determination at the conclusion of mixing and allow the grout to cure for the period of time in seconds listed in Table A3.1 corresponding to the speed index assigned by the manufacturer. Once the cure time has elapsed, immediately load the bar with the ram. A load level of 4000 lb must be achieved within 3 s of the start of loading.

A3.3 Cartridge Equivalent Length Requirements

A3.3.1 Cartridges of chemical grouting materials shall contain sufficient volume to fill the annulus between the bolt and:

<table>
<thead>
<tr>
<th>Speed Index</th>
<th>Maximum(^a) Cure Time, s</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>240</td>
<td>240</td>
</tr>
<tr>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>1000</td>
<td>&gt;600</td>
</tr>
</tbody>
</table>

\(^a\)To achieve 4000-lb test load (see A3.2.1.1).
borehole wall as specified in A3.3.2. The volume will be identified by an equivalent length designation (ft) indicating the length of borehole grouted by the cartridge for the nominal bolt/borehole combination used.

A3.3.2 Minimum cartridge volumes required for specified equivalent length designations shall be calculated by using the following equation where the equivalent length (EL) is equal to the bolt length:

\[ V_g = V_h - V_b \]

where

\[ V_g = \text{required grout volume, in.}^3 \]
\[ V_h = \text{borehole volume, in.}^3 \]
\[ V_b = \text{bolt volume, in.}^3 \]

The borehole volume shall be calculated by using the following:

\[ \text{Borehole Diameter} = \text{Nominal Diameter} + 0.043 \text{ in.} \]
\[ \text{Borehole Length} = \text{Bolt Length} + 1 \text{ in.} \]

The bolt volume shall be based on nominal reinforcing bar cross sections in accordance with Specification A 615.

Note A3.5—When bolts with cross-sectional areas different from those specified in Specification A 615 are used, adjustments to the calculated equivalent length may be necessary.

A3.4 Grout Application Class

A3.4.1 Chemical grouting materials shall be assigned a class designation to indicate recommended product application.

A3.4.1.1 Chemical grouting materials for use in fully grouted or partially grouted nontensioned applications shall be designated as Class I.

A3.4.1.2 Chemical grouting materials used to supplement mechanical anchorage devices shall be designated as Class II.

A3.4.1.3 Chemical grouting materials used to provide anchorage (chemical anchor only) for tensioned bolts shall be designated as Class III.

A3.4.2 Chemical grouting materials serving more than one application class may be assigned a multiple class designation (that is, Class I, III).

A3.5 Product Marking

A3.5.1 Cartridges of chemical grouting materials are not required to be marked. Containers of chemical grouting cartridges shall be labeled to provide the following information:

A3.5.1.1 Container labels shall provide general product information including manufacturer, formulation designation, and number of cartridges in the container as shipped.

A3.5.1.2 Container labels shall provide nominal system data including recommended hole diameter, bolt diameter, and cartridge equivalent footage (see A3.3). Labels may list more than one hole/bolt/eq.ft. combination if multiple product applications are possible.

A3.5.1.3 Container labels shall provide standard data including cartridge length and diameter, speed index (see A3.2), application class (see A3.4), and “use by (date).”

A3.5.1.4 Nominal installation data including recommended mix time (seconds) and mixing speed (r/min) shall be included on, or within, the container.

A3.5.1.5 Strength index shall be placed on the container label, within the container, or in the manufacturers’ literature.
APPENDIXES
(Nonmandatory Information)

X1. SELECTING APPROPRIATE GRADE RATING FOR BEARING PLATES AND HEADER PLATES

X1.1 The establishment of grade increments for bearing plates and header plates described in 7.4.1 enables the purchaser to select the appropriate relationship between the performance characteristics of the bolts and plates that is effective for the particular rock and ground conditions at the site of intended use.

X1.2 After determining the desired relationship between the grade rating of the plate and the minimum yield load for the grade and diameter of the bolt, the purchaser can order under this specification an appropriate grade rating for the bearing plate or header plate.

X2. EXPANSION SHELL TYPES

X2.1 Expansion shells are generally of two types. The first type is self-supporting by some means integral to the shell, such as a bail. The second type requires support to remain in position during installation until anchored. This type may use support such as special nuts on the thread or plastic sleeves, although other means of support may be used. These support devices (bail, support nuts, etc.) should be of a special design that is capable of supporting the shell during installation but should not interfere with the proper tensioning of the bolt after the shell is anchored.

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Standard Specification for
Hardened Steel Washers

This standard is issued under the fixed designation F 436; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (\(\epsilon\)) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers the chemical, mechanical, and dimensional requirements for hardened steel washers for use with fasteners having nominal thread diameters of \(\frac{1}{4}\) through 4 in. These washers are intended for general-purpose mechanical and structural use with bolts, nuts, studs, and other internally and externally threaded fasteners. These washers are suitable for use with fasteners covered in Specifications A 325, A 354, A 449, and A 490.

1.2 The washers are designated by type denoting the material and by style denoting the shape.

1.2.1 The types of washers covered are:

1.2.1.1 Type 1—Carbon steel.

1.2.1.2 Type 3—Weathering steel. Atmospheric corrosion resistance and weathering characteristics are comparable to that of steels covered in Specifications A 588/A 588M and A 709/A 709M. The atmospheric corrosion resistance of these steels is substantially better than that of carbon steel with or without copper addition. See 5.1. When properly exposed to the atmosphere, these steels can be used bare (uncoated) for many applications.

1.2.2 The styles of washers covered are:

1.2.2.1 Circular—Circular washers in nominal bolt sizes \(\frac{1}{4}\) through 4 in. suitable for applications where sufficient space exists and angularity permits.

1.2.2.2 Beveled—Beveled washers are square or rectangular, in nominal sizes \(\frac{1}{2}\) through 1 \(\frac{1}{2}\) in., with a beveled 1 to 6 ratio surface for use with American standard beams and channels.

1.2.2.3 Clipped—Clipped washers are circular or beveled for use where space limitations necessitate that one side be clipped.

*Note: A complete metric companion to Specification F 436 has been developed—Specification F 436M; therefore no metric equivalents are presented in this specification.

1.2.2.4 Extra Thick—Extra thick washers are circular washers in nominal sizes \(\frac{1}{2}\) through 1 \(\frac{1}{2}\) in., with a nominal thickness of \(\frac{1}{16}\) in. suitable for structural applications with oversized holes.

1.3 Terms used in this specification are defined in Specification F 1789 unless otherwise defined herein.

2. Referenced Documents

2.1 ASTM Standards:

A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A 325 Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength

A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners

A 449 Specification for Quenched and Tempered Steel Bolts and Studs

A 490 Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength

A 588/A 588M Specification for High-Strength Low-Alloy Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4 in. [100 mm] Thick

A 709/A 709M Specification for Carbon and High-Strength Low-Alloy Structural Steel Shapes, Plates, and Bars and Quenched-and-Tempered Alloy Structural Steel Plates for Bridges

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel

D 3951 Practice for Commercial Packaging

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

*Summary of Changes section appears at the end of this standard.
3. Ordering Information

3.1 Orders for hardened steel washers under this specification shall include the following:
   3.1.1 ASTM designation and year of issue,
   3.1.2 Quantity (number of pieces by size),
   3.1.3 Type and Style (see 1.2.1 and 1.2.2),
   3.1.4 Zinc Coating—Specify the zinc coating process required, for example, hot-dip, mechanically deposited, or no preference (see 4.3),
   3.1.5 Dimensions, nominal size, and other dimensions, if modified from those covered in this specification,
   3.1.6 Specify if inspection at point of manufacture is required,
   3.1.7 Specify if manufacturer’s certification or test reports, or both, are required, and
   3.1.8 Special requirements.

4. Materials and Manufacture

4.1 Steel used in the manufacture of washers shall be produced by the open-hearth, basic-oxygen, or electric-furnace process.

4.2 Washers up to and including 1½ in. in bolt size shall be through hardened. Washers over 1½ in. may be either through hardened or carburized at the option of the manufacturer.

4.3 Zinc Coatings, Hot-Dip and Mechanically Deposited:
   4.3.1 When zinc-coated washers are required, the purchaser shall specify the zinc coating process, for example, hot-dip, mechanically deposited, or no preference.
   4.3.2 When hot-dip is specified the washers shall be zinc coated by the hot-dip process in accordance with the requirements of Class C of Specification A 153/A 153M.
   4.3.3 When mechanically deposited is specified the washers shall be coated by the mechanical-deposition process in accordance with Specification B 695.
   4.3.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification A 153/A 153M, Class C, or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. Threaded components (bolt and nuts) shall be coated by the same zinc-coating process and the supplier’s option is limited to one process per item with no mixed processes in a lot.

4.3.5 If washers are heat treated by a subcontractor, they shall be returned to the manufacturer for testing prior to shipment to the purchaser.

5. Chemical Composition

5.1 Type 1 and Type 3 washers shall conform to the chemical composition specified in Table 1. For Type 3 see Guide G 101 for methods of estimating corrosion resistance of low alloy steels.

5.2 Product analysis may be made by the purchaser from finished material representing each lot of washers. The chemical composition shall conform to the requirements of 4.1 and 5.1.

5.3 Individual heats of steel are not identified in the finished product.

5.4 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 Through hardened washers shall have a hardness of 38 to 45 HRC, except when zinc-coated by the hot-dip process, in which case they shall have a hardness of 26 to 45 HRC.

6.2 Carburized washers shall be carburized to a minimum depth of 0.015 in. and shall have a surface hardness of 69 to 73 HRA or 79 to 83 HR15N, except when zinc-coated by the hot-dip process, in which case they shall have a hardness of 63 to 73 HRA or 73 to 83 HR15N.

6.3 Carburized and hardened washers shall have a minimum core hardness of 30 HRC or 65 HRA.

7. Dimensions and Tolerances

7.1 All circular and clipped circular washers shall conform to the dimensions shown in Table 2 and Table 3.

7.2 All square beveled and clipped square beveled washers shall conform to the dimensions shown in Table 3 and Table 4. In addition, rectangular beveled and clipped rectangular beveled washers shall conform to the dimensions shown in Table 3 and Table 4, except that one side may be longer than shown for the “A” dimension.

7.3 Unless otherwise stated in the inquiry or purchase order, plain (uncoated) hardened steel circular washers shall be furnished. Where corrosion-preventive treatment is required, washers shall be coated as agreed upon between the manufacturer and the purchaser.

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* Annual Book of ASTM Standards, Vol 03.02.
### TABLE 2  Hardened Circular, Clipped Circular, and Extra-Thick Washers

**NOTE 1**—Tolerances are as noted in table on washer dimension tolerances.

<table>
<thead>
<tr>
<th>Circular and Extra Thick</th>
<th>Circular and Clipped</th>
<th>Extra Thick</th>
<th>Clipped</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nominal Size</strong></td>
<td><strong>Nominal Outside Diameter (OD), in.</strong></td>
<td><strong>Nominal Inside Diameter (ID), in.</strong></td>
<td><strong>Thickness (T), in.</strong></td>
</tr>
<tr>
<td>1/4</td>
<td>0.625</td>
<td>0.281</td>
<td>min 0.051 max 0.080</td>
</tr>
<tr>
<td>5/16</td>
<td>0.688</td>
<td>0.344</td>
<td>0.051</td>
</tr>
<tr>
<td>3/8</td>
<td>0.813</td>
<td>0.406</td>
<td>0.051</td>
</tr>
<tr>
<td>7/16</td>
<td>0.922</td>
<td>0.469</td>
<td>0.051</td>
</tr>
<tr>
<td>1/2</td>
<td>1.063</td>
<td>0.531</td>
<td>0.097</td>
</tr>
<tr>
<td>9/16</td>
<td>1.188</td>
<td>0.625</td>
<td>0.110</td>
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<tr>
<td>5/8</td>
<td>1.313</td>
<td>0.688</td>
<td>0.122</td>
</tr>
<tr>
<td>3/4</td>
<td>1.468</td>
<td>0.813</td>
<td>0.122</td>
</tr>
<tr>
<td>7/8</td>
<td>1.750</td>
<td>0.938</td>
<td>0.136</td>
</tr>
<tr>
<td>1</td>
<td>2.000</td>
<td>1.125</td>
<td>0.136</td>
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<td>1 1/8</td>
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<td>1.250</td>
<td>0.136</td>
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<tr>
<td>1 1/4</td>
<td>2.500</td>
<td>1.375</td>
<td>0.136</td>
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<td>1 3/8</td>
<td>2.750</td>
<td>1.500</td>
<td>0.136</td>
</tr>
<tr>
<td>1 1/2</td>
<td>3.000</td>
<td>1.625</td>
<td>0.136</td>
</tr>
<tr>
<td>1 5/8</td>
<td>3.375</td>
<td>1.875</td>
<td>0.178b</td>
</tr>
<tr>
<td>2</td>
<td>3.750</td>
<td>2.125</td>
<td>0.178b</td>
</tr>
<tr>
<td>2 1/4</td>
<td>4.000</td>
<td>2.375</td>
<td>0.24c</td>
</tr>
<tr>
<td>2 1/2</td>
<td>4.500</td>
<td>2.625</td>
<td>0.24c</td>
</tr>
<tr>
<td>2 3/4</td>
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<td>2.875</td>
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<td>3.375</td>
<td>0.24c</td>
</tr>
<tr>
<td>3 1/2</td>
<td>6.500</td>
<td>3.625</td>
<td>0.24c</td>
</tr>
<tr>
<td>3 3/4</td>
<td>7.000</td>
<td>3.875</td>
<td>0.24c</td>
</tr>
<tr>
<td>4</td>
<td>7.500</td>
<td>4.125</td>
<td>0.24c</td>
</tr>
</tbody>
</table>

---

*A Clipped edge E shall be not closer than 7/8 of the bolt diameter from the center of the washer.

b 3/16 in. nominal.
c 1/4 in. nominal.
8. Workmanship, Finish, and Appearance

8.1 Washers shall be free of excess mill scale, excess coatings and foreign material on bearing surfaces. Arc and gas cut washers shall be free of metal spatter.

9. Sampling and Number of Tests

9.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated.

9.2 When additional tests are specified in the inquiry or purchase order, a lot, for purposes of selecting test samples, shall consist of all material offered for inspection at one time that has the following common characteristics:

9.2.1 Same nominal size.
9.2.2 Same material grade.

9.2.3 Same nominal post treatment (heat treatment or coating or both).

9.3 From each lot described in 9.2, the number of specimens tested for each required property shall be as follows:

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and under</td>
<td>1</td>
</tr>
<tr>
<td>801 to 8000</td>
<td>2</td>
</tr>
<tr>
<td>8001 to 22 000</td>
<td>3</td>
</tr>
<tr>
<td>Over 22 000</td>
<td>5</td>
</tr>
</tbody>
</table>

10. Test Methods

10.1 Hardness:

10.1.1 Non-carburized Washers—A minimum of two readings shall be taken 180° apart on at least one face at a minimum depth of 0.015 in.

10.1.2 Carburized Washers—A minimum of two readings shall be taken 180° apart on at least one face.
10.2 Hardness tests shall be performed in accordance with the Rockwell test method specified in Test Methods F 606.

11. Inspection

11.1 The manufacturer shall afford the purchaser’s inspector all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with this specification. Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer’s operations. All tests and inspections shall be made at the place of manufacture, unless otherwise agreed to.

11.2 If other than the normal inspection for continuous mass production of parts as stipulated in 9.1 is required by the purchaser, it shall be specified in the inquiry and contract order.

12. Rejection and Rehearing

12.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

13. Certification and Test Report

13.1 Upon request of the purchaser in the contract or order, a manufacturer’s certification that the material was manufactured and tested in accordance with this specification, together with a report of the latest mechanical tests of each stock size in each shipment, shall be furnished at the time of shipment.

13.2 Data contained in the certified test report shall include material grade and hardness tests.

14. Responsibility

14.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

15. Product Marking

15.1 Washers shall be marked with a symbol, or other distinguishing marks, to identify the manufacturer or private label distributor, as appropriate.

15.2 Additionally, Type 3 weathering steel washers shall be identified with the symbol “3”.

15.3 Additional identification or distinguishing marks, or both, may be used by the manufacturer.

15.4 All marking symbols shall be depressed on one face of the washer.

15.5 Type and manufacturer’s or private label distributor’s identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

15.6 It is possible that during the clipping of circular washers the marking symbols may be removed. This is acceptable provided that the majority of washers in the lot still display the identification marks.

16. Packaging and Package Marking

16.1 Packaging:

16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

16.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

16.2 Package Marking:

16.2.1 Each shipping unit shall include or be plainly marked with the following information:

16.2.1.1 ASTM designation and type,

16.2.1.2 Size,

16.2.1.3 Name and brand or trademark of the manufacturer,

16.2.1.4 Number of pieces,

16.2.1.5 Purchase order number, and

16.2.1.6 Country of origin.

17. Keywords

17.1 carbon steel; steel; washers; weathering steel

SUPPLEMENTARY REQUIREMENTS

S1. Surface Roughness

S1.1 Washers shall have a multidirectional lay with a surface roughness not exceeding 750 μin. in height including any flaws in or on the surface.

S1.2 Burrs shall not exceed 0.01 in. in height.
SUMMARY OF CHANGES

This section identifies the location of selected changes to this standard that have been incorporated since the F 463-02 issue. For the convenience of the user, Committee F16 has highlighted those changes that impact the use of this standard. This section may also include descriptions of the changes or reasons for the changes, or both. (Approved Oct. 1, 2003).

(1) Added Section 1.3 that references Terminology F 1789 for definitions of terms.
(2) Added Section 1.2.2.4. that discusses the extra thick washer.
(3) Revised Table 2, providing for extra-thick washers.
(4) Revised Table 3 so the tolerances are more progressive through the range of diameter.

This section identifies the location of selected changes to this standard that have been incorporated since the F 463-93 issue. For the convenience of the user, Committee F16 has highlighted those changes that impact the use of this standard. This section may also include descriptions of the changes or reasons for the changes, or both. (Approved October 10, 2002.)

(1) Changed fractions to decimals except for nominal size.
(2) Changed “Bolt Size” to “Nominal Size” in column headings.
(3) In Table 2, added 9⁄16-in. size.

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1. Scope

1.1 This specification covers the chemical, mechanical, and dimensional requirements for metric hardened steel washers for use with fasteners having nominal thread diameters M12 through M100. These washers are intended for general-purpose mechanical and structural use with bolts, nuts, studs, and other internally and externally threaded fasteners. These washers are suitable for use with fasteners covered in Specifications A 325M, A 490M, A 563M and with fasteners of Specification F 568 property classes 8.8 and higher.

1.2 The types of washers covered in this specification are:

1.2.1 Type 1—Washers made of carbon steel.

1.2.2 Type 3—Washers made of steel having atmospheric corrosion resistance and weathering characteristics comparable to that of steels covered in Specifications A 242/A 242M, A 588/A 588M, and A 709. The atmospheric corrosion resistance of these steels is substantially better than that of carbon steel with or without copper addition. See 5.1. When properly exposed to the atmosphere, these steels can be used bare (uncoated) for many applications.

1.3 The styles of washers covered in this specification are:

1.3.1 Circular Washers—Circular washers in nominal sizes 12 mm through 100 mm, are suitable for applications where sufficient space exists and angularity permits.

1.3.2 Beveled Washers—Beveled washers are square and rectangular, in nominal sizes 12 mm through 36 mm, with a beveled 1:6 surface for use with American Standard beams and channels.

1.3.3 Clipped Washers—Clipped washers are circular or beveled for use where space limitations necessitate that one side be clipped.

Note 1—This specification is the metric counterpart of Specification F 436.

1.4 Terms used in this specification are defined in Terminology F 1789 unless otherwise defined herein.

2. Referenced Documents

2.1 ASTM Standards:

A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
A 242/A 242M Specification for High-Strength Low-Alloy Structural Steel
A 325M Specification for Structural Bolts, Steel Heat Treated 830 MPa Minimum Tensile Strength [Metric]
A 490M Specification for High-Strength Steel Bolts, Classes 10.9 and 10.9.3, for Structural Steel Joints [Metric]
A 563M Specification for Carbon and Alloy Steel Nuts [Metric]
A 588/A 588M Specification for High-Strength Low-Alloy Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4 in. [100 mm] Thick
A 709/A 709M Specification for Carbon and High-Strength Low-Alloy Structural Steel Shapes, Plates, and Bars and Quenched-and-Tempered Alloy Structural Steel Plates for Bridges
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
D 3951 Practice for Commercial Packaging
F 568M Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners

* A Summary of Changes section appears at the end of this standard.
3. Ordering Information

3.1 Orders for washers under this specification shall include the following:

3.1.1 Quantity,

3.1.2 Name of product, (that is, circular washer, beveled washer, clipped circular washer, or clipped beveled washer),

3.1.3 Coating, if required (that is, hot-dip galvanized, mechanically galvanized, etc.),

3.1.3.1 When galvanized washers are specified, the type of galvanizing, such as hot-dip or mechanical (see 6.1 and 6.3),

3.1.3.1.1 When the type of galvanizing is not specified, the manufacturer, at his option, may furnish hot-dip or mechanically galvanized washers,

3.1.4 Dimensions, nominal size, and other dimensions, if modified from those covered in this specification,

3.1.5 Material type of washer (that is, Type 1 or Type 3),

3.1.5.1 When the type is not specified, either Type 1 or Type 3 washers may be supplied when permitted by the purchaser.

3.1.5.2 When atmospheric corrosion resistance is required, Type 3 washers shall be specified by the purchaser.

3.1.6 Surface roughness control (see S1),

3.1.7 ASTM designation and year of issue, and

3.1.8 Any special requirements.

NOTE 2—Two examples of ordering descriptions follow: (1) 1000 pieces, circular washers, hot-dip galvanized, 24 mm, Type 1 ASTM F 436M, dated _______. (2) 5000 pieces, beveled washers, 22 mm, Type 3, ASTM F 436M, dated _______.

4. Materials and Manufacture

4.1 Steel used in the manufacture of washers shall be produced by the open-hearth, basic-oxygen, or electric-furnace process.

4.2 All washers in nominal sizes 12 through 36 mm, shall be through-quenched-and-tempered. Washers in nominal sizes larger than 36 mm may be either through-quenched-and-tempered or carburized, quenched-and-tempered at the manufacturer’s option.

4.3 Hot-dip galvanized washers shall be hot-dip galvanized in accordance with the requirements for Class C of Specification A 153/A 153M. Mechanically galvanized washers shall be mechanically zinc-coated, and the coating and coated washers shall conform to the requirements for Class 50 of Specification B 695.

4.4 If washers are heat treated by a subcontractor, they shall be returned to the manufacturer for testing prior to shipment to the purchaser.

5. Chemical Composition

5.1 Type 1 and Type 3 washers shall conform to the chemical composition requirements specified in Table 1. For Type 3 see Guide G 101 for methods of estimating corrosion resistance of low alloy steels.

5.2 Product analysis may be made by the purchaser from finished material representing each lot of washers. The chemical composition shall conform to the requirements of 4.1 and 5.1.

5.3 Individual heats of steel are not identified in the finished product.

5.4 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 Through-quenched-and-tempered washers shall have a Rockwell hardness of 38 to 45 HRC, except when hot-dip galvanized, in which case they shall have a Rockwell hardness of 26 to 45 HRC.

6.2 Carburized, quenched-and-tempered washers shall be carburized to a minimum depth of 0.40 mm and shall have a Rockwell hardness of 69 to 73 HRA.

6.3 When mechanically galvanized, washers shall have the same hardness range as noncoated washers.

7. Dimensions and Tolerances

7.1 Circular and clipped circular washers shall conform to dimensions given in Table 2. All dimensions apply prior to plating or coating.

7.1.1 The axis of the inside hole shall be located at true position with respect to the axis of the washer circumference within a tolerance zone having a diameter of 0.6 mm for washers of nominal sizes 16 mm and smaller and 0.9 mm for washers of nominal sizes 20 mm and larger.

7.1.2 Washers shall be flat within 0.01 mm/mm outside diameter.

7.1.3 As a result of the punching process, the inside diameter of the washer generally consists of three distinct sections.

TABLE 1 Chemical Requirements

<table>
<thead>
<tr>
<th>Element</th>
<th>Type 1</th>
<th>Type 3</th>
</tr>
</thead>
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</tr>
<tr>
<td>Heat analysis</td>
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<td>Product analysis</td>
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<td>Product analysis</td>
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<tr>
<td>Heat analysis</td>
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<td>Product analysis</td>
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</tr>
<tr>
<td>Product analysis</td>
<td>0.22–0.48</td>
<td></td>
</tr>
</tbody>
</table>

* Type 3 steel washers may also be manufactured from any of the steels listed in Table 2 of Specification F 568.
On the punch entry side of the washer there is some drawing in of the material resulting in a rounded corner section, following which is a substantially parallel section, and finally at the exit side a tapered breakout may occur (see Fig. 1). The parallel sided section of the washer inside diameter shall be within the limits specified in Table 2, however, the specified maximum inside diameter may be exceeded at the washer face on the breakout side by a maximum taper allowance of 25 % of the specified maximum washer thickness for each size.

7.2 Beveled washers shall conform to dimensions in accordance with ANSI B18.23.2M.

7.3 Clipped beveled washers shall conform to dimensions for beveled washers in accordance with ANSI B18.23.2, except that one edge may be clipped off not closer than 0.0875 times the washer nominal size from the center of the hole.

8. Workmanship, Finish, and Appearance

8.1 Washers shall be free of excess mill scale, excess coatings, and foreign material on bearing surfaces. Arc and gas cut washers shall be free of metal spatter.

### TABLE 2 Dimensions of Circular Washers

<table>
<thead>
<tr>
<th>Nominal Washer Size, mm</th>
<th>Inside Diameter (A), mm</th>
<th>Outside Diameter (B), mm</th>
<th>Thickness (C), mm</th>
<th>Clipped Width (E), mm, min</th>
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<tbody>
<tr>
<td></td>
<td>max</td>
<td>min</td>
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<td>min</td>
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<td>12</td>
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<tr>
<td>14</td>
<td>16.4</td>
<td>16.0</td>
<td>30.0</td>
<td>28.7</td>
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<tr>
<td>16</td>
<td>18.4</td>
<td>18.0</td>
<td>34.0</td>
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<td>22.0</td>
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<td>40.4</td>
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<td>24.0</td>
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<td>42.4</td>
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<td>26.0</td>
<td>50.0</td>
<td>48.4</td>
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<td>27</td>
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<td>33.6</td>
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<td>58.1</td>
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<td>36</td>
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<td>39.0</td>
<td>72.0</td>
<td>70.1</td>
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<td>48</td>
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<td>80</td>
<td>86.9</td>
<td>86.0</td>
<td>142.0</td>
<td>139.5</td>
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<td>90</td>
<td>96.9</td>
<td>96.0</td>
<td>159.0</td>
<td>156.5</td>
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<tr>
<td>100</td>
<td>107.9</td>
<td>107.0</td>
<td>176.0</td>
<td>173.5</td>
</tr>
</tbody>
</table>

*Nominal washer sizes are intended for use with fasteners of the same nominal thread diameter.

Washers may be clipped on one side not closer to the center of the washer than width E.

9. Sampling and Number of Tests and Retests

9.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily necessary.

9.2 When specified in the purchase order, the manufacturer shall furnish a test report certified to be the last complete set of mechanical tests for each stock size in each shipment.

9.3 When the purchaser requires that additional tests be performed by the manufacturer to determine that the properties of products in an individual shipment are within specified limits, the purchaser shall specify the testing requirements, including the sampling plan and basis of acceptance, in the inquiry and purchase order.

9.3.1 When the purchaser does not specify the sampling plan and basis of acceptance the conditions in 9.3.1.1 through 9.3.1.3 shall apply:

9.3.1.1 The lot, for purposes of selecting samples, shall consist of all washers offered for inspection and testing, at one time, that are the same type, style, nominal size, and surface finish.

9.3.1.2 From each lot, samples shall be selected at random and tested for each requirement, except as specified in 9.3.1.3, in accordance with Table 3.
9.3.1.3 When determining the weight of coating of plated and coated washers, the sampling plan defined in 9.3.1.2 shall apply, except that in no case shall the sample consist of less than three washers.

10. Test Methods

10.1 Hardness tests shall be performed in accordance with Test Methods F 606M.

11. Inspection

11.1 The inspector representing the purchaser shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser’s representative shall be made prior to shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

11.2 If other than the normal inspection for continuous mass production of parts as stipulated in 9.1 is required by the purchaser, it shall be specified in the inquiry and contract order.

12. Rejection

12.1 Unless otherwise specified, any rejection based on tests made in accordance with this specification shall be reported to the manufacturer within 30 working days from the receipt of samples by the purchaser.

13. Certification and Test Report

13.1 Upon request of the purchaser in the contract or order, a manufacturer’s certification that the material was manufactured and tested in accordance with this specification, together with a report of the latest mechanical tests of each stock size in each shipment, shall be furnished at the time of shipment.

13.2 Data contained in the certified test report shall include material grade and hardness tests.

14. Responsibility

14.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

15. Product Marking

15.1 Washers shall be marked with a symbol, or other distinguishing marks, to identify the manufacturer or private label distributor, as appropriate.

15.2 Additionally, washers shall be marked to identify their being metric size. Preferably, the metric marking shall be the symbol “M,” but may be of other distinguishing design as determined by the manufacturer.

15.3 Additionally, Type 3 washers shall be identified with the symbol “3.”

15.4 Additional identification or distinguishing marks, or both, may be used by the manufacturer.

15.5 All marking symbols shall be depressed on one face of the washer.

15.6 Type and manufacturer’s or private label distributor’s identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

15.7 It is possible that during the clipping of circular washers, the marking symbols may be removed. This is acceptable provided the majority of washers in the lot still display the identification marks.

16. Packaging and Package Marking

16.1 Packaging:

16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

16.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

16.2 Package Marking:

16.2.1 Each shipping unit shall include or be plainly marked with the following information:

- 16.2.1.1 ASTM designation,
- 16.2.1.2 Size,
- 16.2.1.3 Name and brand or trademark of the manufacturer,
- 16.2.1.4 Number of pieces,
- 16.2.1.5 Purchase order number, and
- 16.2.1.6 Country of origin.

17. Keywords

17.1 carbon steel; metric; steel; washers; weathering steel
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order. Details of these supplementary requirements shall be agreed upon in writing between the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Surface Roughness

S1.1 Washers shall have a multi-directional lay with a surface roughness not exceeding 19 µm in height including any flaws in or on the surface.

S1.2 Burrs shall not exceed 0.25 mm in height.

SUMMARY OF CHANGES

Committee F16 has identified the location of selected changes to this standard since the last issue (F 436M–93 (2000)) that may impact the use of this standard. (Approved Oct. 1, 2003)

(1) Added Section 1.4 that references Terminology F 1789 for definitions of terms.

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Standard Specification for Nonferrous Nuts for General Use

This standard is issued under the fixed designation F 467; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers the requirements for commercial wrought nonferrous nuts 0.250 to 1.500 in. inclusive in diameter in a number of alloys in common use and intended for general service applications.

1.2 Applicable bolts, cap screws, and studs for use with nuts covered by this specification are covered by Specification F 468.

Note 1—A complete metric companion to Specification F 467 has been developed—F 467M; therefore no metric equivalents are presented in this specification.

2. Referenced Documents

2.1 ASTM Standards:

B 154 Test Method for Mercurous Nitrate Test for Copper and Copper Alloys

B 446 Specification for Nickel-Chromium-Molybdenum-Columbium-Alloy (UNS N06625), Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219), and Nickel-Chromium-Molybdenum-Tungsten Alloy (UNS N06650) Rod and Bar

D 3951 Practice for Commercial Packaging

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 34 Test Methods for Chemical Analysis of Aluminum and Aluminum Base Alloys

E 38 Methods for Chemical Analysis of Nickel-Chromium and Nickel-Chromium-Iron Alloys

E 53 Test Methods for Determination of Copper in Unalloyed Copper by Gravimetry

E 54 Test Methods for Chemical Analysis of Special Brasses and Bronzes

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)

E 75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys

E 76 Test Methods for Chemical Analysis of Nickel-Copper Alloys

E 92 Test Method for Vickers Hardness of Metallic Materials

E 101 Test Method for Spectrographic Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique

E 120 Test Methods for Chemical Analysis of Titanium and Titanium Alloys

E 165 Practice for Liquid Penetrant Examination

E 227 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique

E 354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys

E 478 Test Methods for Chemical Analysis of Copper Alloys

E 1409 Test Method for Determination of Oxygen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique

F 468 Specification for Nonferrous Bolts, Hex Cap Screws, and Studs for General Use

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

2.2 ASME Standards:

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3. Ordering Information

3.1 Orders for nuts under this specification shall include the following information:

3.1.1 Quantity (number of pieces of each item and size);
3.1.2 Name of item;
3.1.3 Size (diameter and threads per inch);
3.1.4 Alloy number (Table 1);
3.1.5 Stress relieving, if required (4.2.3);
3.1.6 “Shipment lot” testing, as required (Section 9);
3.1.7 Source inspection, if required (Section 14);
3.1.8 Certificate of compliance or test report, if required (Section 16);
3.1.9 Additional requirements, if any, to be specified on the purchase order (4.2.1, 7.2, 8.2, 12.1, and 13.1),
3.1.10 Supplementary requirements, if any; and
3.1.11 ASTM designation (including year or published date).

Note 2—A typical ordering description is as follows: 10 000 pieces, Hex Nut, 0.250”-20, Alloy 270, Furnish Certificate of Compliance, Supplementary Requirement S 1, ASTM Specification F 467-XX.
<table>
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<tr>
<th>UNS Designation Number</th>
<th>Alloy</th>
<th>General Name</th>
<th>Aluminum, min</th>
<th>Copper, min</th>
<th>Iron, max</th>
<th>Manganese, max</th>
<th>Nickel, max</th>
<th>Phosphorus</th>
<th>Silicon, max</th>
<th>Lead, max</th>
<th>Arsenic, max</th>
<th>Zinc, max</th>
<th>Brass, min</th>
<th>Tin, max</th>
<th>Arsenic, max</th>
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<td>110</td>
<td>ETP copper</td>
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<td>99.9</td>
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<td>0.015</td>
<td>0.05</td>
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<td></td>
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<td>brass</td>
<td>270</td>
<td>63.0–68.5</td>
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<td>0.10</td>
<td>balance</td>
<td>0.05</td>
<td>0.20</td>
<td>0.01</td>
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<td>0.20–0.50</td>
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<td>0.10</td>
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<td>0.01</td>
<td>0.05</td>
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<td>0.20–0.50</td>
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<td>0.01</td>
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<td>0.20</td>
<td>0.01</td>
<td>0.05</td>
<td>0.20–0.50</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*Elements shown as balance shall be arithmetically computed by deducting the sum of the other named elements from 100.

*Copper plus specified elements = 99.8 min; copper plus silver = 88.5–91.5.

*Cobalt is to be counted as nickel.

*Minimum content of copper plus all other elements with specified limits shall be 99.5%.

*An alloy containing as high as 2.6% silicon is acceptable provided the sum of all the elements other than copper, silicon, and iron does not exceed 0.30%.
### TABLE 1
Continued

Nickel and Nickel-Base Alloys

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<thead>
<tr>
<th>UNS Designation Number</th>
<th>Alloy</th>
<th>General Name</th>
<th>Aluminum, max</th>
<th>Carbon, max</th>
<th>Chromium, max</th>
<th>Copper, max</th>
<th>Iron, max</th>
<th>Manganese, max</th>
<th>Nickel&lt;sup&gt;A&lt;/sup&gt;</th>
<th>Phosphorus, max</th>
<th>Silicon, max</th>
<th>Titanium, max</th>
<th>Cobalt, max</th>
<th>Molybdenum, max</th>
<th>Sulfur, max</th>
<th>Vanadium, max</th>
<th>Tungsten, max</th>
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<td>N10001</td>
<td>335</td>
<td>Ni-Mo</td>
<td>0.05</td>
<td>1.0 max</td>
<td>4.0–6.0</td>
<td>1.0 balance</td>
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<td>1.00</td>
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<td>0.030</td>
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<td>0.35 max</td>
<td>3.0–4.5</td>
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</tr>
<tr>
<td>N10276</td>
<td>276</td>
<td>Ni-Mo-Cr</td>
<td>0.02</td>
<td>1.45–16.5</td>
<td>4.0–7.0</td>
<td>1.00</td>
<td>0.040</td>
<td>0.08</td>
<td>2.50</td>
<td>0.030</td>
<td>0.030</td>
<td>0.2–0.4</td>
<td>0.35 max</td>
<td>3.0–4.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N04400</td>
<td>400</td>
<td>Ni-Cu Class A</td>
<td>0.3</td>
<td>balance</td>
<td>2.5</td>
<td>2.0</td>
<td>0.5</td>
<td>5.0</td>
<td>0.025</td>
<td>0.030</td>
<td>0.030</td>
<td>0.02–0.25</td>
<td>0.030</td>
<td>3.0–4.5</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>N04405</td>
<td>405</td>
<td>Ni-Cu Class B</td>
<td>0.3</td>
<td>balance</td>
<td>2.0</td>
<td>1.5</td>
<td>0.5</td>
<td>58.0 min</td>
<td>0.015</td>
<td>0.030</td>
<td>0.030</td>
<td>0.02–0.25</td>
<td>0.030</td>
<td>3.0–4.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N05500</td>
<td>500</td>
<td>Ni-Cu-Al</td>
<td>2.30–3.15</td>
<td>0.40 max</td>
<td>5.0</td>
<td>0.5 max</td>
<td>0.015</td>
<td>0.50 max</td>
<td>0.020</td>
<td>0.030</td>
<td>0.030</td>
<td>0.02–0.25</td>
<td>0.030</td>
<td>3.0–4.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N06625</td>
<td>625</td>
<td>Ni-Cr-Mo-Cb</td>
<td>0.010</td>
<td>20.0–23.0</td>
<td>50.0 max</td>
<td>58.0 min</td>
<td>0.015</td>
<td>0.50 max</td>
<td>0.020</td>
<td>0.030</td>
<td>0.030</td>
<td>0.02–0.25</td>
<td>0.030</td>
<td>3.0–4.5</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>N06686</td>
<td>686</td>
<td>Ni-Cr-Mo-W</td>
<td>0.010 max</td>
<td>19.0–23.0</td>
<td>5.0 max</td>
<td>0.75 max</td>
<td>0.04 max</td>
<td>0.08 max</td>
<td>0.020</td>
<td>0.030</td>
<td>0.030</td>
<td>0.02–0.25</td>
<td>0.030</td>
<td>3.0–4.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>A</sup> Elements shown as balance shall be arithmetically computed by deducting the sum of the other named elements from 100.

<sup>B</sup> Cobalt is to be counted as nickel.

<sup>C</sup> Alloy 625 material shall be refined using the electroslag remelting process (ESR), or the vacuum arc remelting process (VAR).
<table>
<thead>
<tr>
<th>UNS Designation Number</th>
<th>Alloy</th>
<th>General Name</th>
<th>Aluminum</th>
<th>Chromium</th>
<th>Copper</th>
<th>Iron, max</th>
<th>Manganese, max</th>
<th>Silicon, max</th>
<th>Titanium, max</th>
<th>Zinc, max</th>
<th>Magnesium</th>
<th>Other Elements, max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>A92024</td>
<td>2024</td>
<td>Aluminum</td>
<td>balance</td>
<td>0.10</td>
<td>3.8–4.9</td>
<td>0.50</td>
<td>0.30–0.9</td>
<td>0.50</td>
<td>0.15</td>
<td>0.25</td>
<td>1.2–1.8</td>
<td>0.05</td>
</tr>
<tr>
<td>A96061</td>
<td>6061</td>
<td>Aluminum</td>
<td>balance</td>
<td>0.04–0.35</td>
<td>0.15–0.40</td>
<td>0.7</td>
<td>0.15</td>
<td>0.40–0.8</td>
<td>0.15</td>
<td>0.25</td>
<td>0.8–1.2</td>
<td>0.05</td>
</tr>
<tr>
<td>A96262</td>
<td>6262</td>
<td>Aluminum</td>
<td>balance</td>
<td>0.04–0.14</td>
<td>0.15–0.40</td>
<td>0.7</td>
<td>0.15</td>
<td>0.40–0.8</td>
<td>0.15</td>
<td>0.25</td>
<td>0.8–1.2</td>
<td>c</td>
</tr>
</tbody>
</table>

*Analysis shall regularly be made only for the elements specified in this table. If, however, the presence of other elements is suspected or indicated in amounts greater than the specified limits, further analysis shall be made to determine that these elements are not present in excess of the specified limits.*

*Titanium + zirconium 0.20 %, max.*

*Lead 0.4–0.7 %; bismuth 0.4–0.7 %.*

---

**TABLE 1 Continued**

Composition, %

Aluminum-Base Alloys

<table>
<thead>
<tr>
<th>UNS Designation Number</th>
<th>Alloy</th>
<th>General Name</th>
<th>Aluminum</th>
<th>Chromium</th>
<th>Copper</th>
<th>Iron, max</th>
<th>Manganese, max</th>
<th>Silicon, max</th>
<th>Titanium, max</th>
<th>Zinc, max</th>
<th>Magnesium</th>
<th>Other Elements, max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A92024</td>
<td>2024</td>
<td>Aluminum</td>
<td>balance</td>
<td>0.10</td>
<td>3.8–4.9</td>
<td>0.50</td>
<td>0.30–0.9</td>
<td>0.50</td>
<td>0.15</td>
<td>0.25</td>
<td>1.2–1.8</td>
<td>0.05</td>
</tr>
<tr>
<td>A96061</td>
<td>6061</td>
<td>Aluminum</td>
<td>balance</td>
<td>0.04–0.35</td>
<td>0.15–0.40</td>
<td>0.7</td>
<td>0.15</td>
<td>0.40–0.8</td>
<td>0.15</td>
<td>0.25</td>
<td>0.8–1.2</td>
<td>0.05</td>
</tr>
<tr>
<td>A96262</td>
<td>6262</td>
<td>Aluminum</td>
<td>balance</td>
<td>0.04–0.14</td>
<td>0.15–0.40</td>
<td>0.7</td>
<td>0.15</td>
<td>0.40–0.8</td>
<td>0.15</td>
<td>0.25</td>
<td>0.8–1.2</td>
<td>c</td>
</tr>
</tbody>
</table>

*Analysis shall regularly be made only for the elements specified in this table. If, however, the presence of other elements is suspected or indicated in amounts greater than the specified limits, further analysis shall be made to determine that these elements are not present in excess of the specified limits.*

*Titanium + zirconium 0.20 %, max.*

*Lead 0.4–0.7 %; bismuth 0.4–0.7 %.*
<table>
<thead>
<tr>
<th>UNS Designation Number</th>
<th>Alloy</th>
<th>General Name</th>
<th>Aluminum, Al</th>
<th>Carbon, C</th>
<th>Iron, Fe</th>
<th>Titanium, Ti</th>
<th>Hydrogen, H</th>
<th>Nitrogen, N</th>
<th>Oxygen, O</th>
<th>Palladium, Pd</th>
<th>Vanadium, V</th>
<th>Chromium, Cr</th>
<th>Molybdenum, Mo</th>
<th>Zirconium, Zr</th>
<th>Tin, Sn</th>
<th>Silicon, Si</th>
<th>Ruthenium, Ru</th>
<th>Residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>R50250</td>
<td>1</td>
<td>Titanium Gr 1</td>
<td>0.10</td>
<td>0.20</td>
<td>balance</td>
<td>0.0125</td>
<td>0.05</td>
<td>0.18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.1 0.4</td>
</tr>
<tr>
<td>R50400</td>
<td>2</td>
<td>Titanium Gr 2</td>
<td>0.10</td>
<td>0.30</td>
<td>balance</td>
<td>0.0125</td>
<td>0.05</td>
<td>0.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>0.1 0.4</td>
</tr>
<tr>
<td>R50700</td>
<td>4</td>
<td>Titanium Gr 4</td>
<td>0.10</td>
<td>0.50</td>
<td>balance</td>
<td>0.0125</td>
<td>0.07</td>
<td>0.40</td>
<td></td>
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<td>0.1 0.4</td>
</tr>
<tr>
<td>R56400</td>
<td>5</td>
<td>Titanium Gr 5</td>
<td>0.10</td>
<td>0.40</td>
<td>balance</td>
<td>0.0125</td>
<td>0.05</td>
<td>0.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.5–4.5</td>
<td></td>
<td></td>
<td></td>
<td>0.1 0.4</td>
</tr>
<tr>
<td>R56401</td>
<td>23</td>
<td>Titanium Ti-6Al-4V ELI</td>
<td>0.08</td>
<td>0.25</td>
<td>balance</td>
<td>0.0125</td>
<td>0.05</td>
<td>0.13</td>
<td>3.5–4.5</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>R52400</td>
<td>7</td>
<td>Titanium Gr 7</td>
<td>0.10</td>
<td>0.30</td>
<td>balance</td>
<td>0.0125</td>
<td>0.05</td>
<td>0.25</td>
<td>0.12–0.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.1 0.4</td>
</tr>
<tr>
<td>R59640</td>
<td>19</td>
<td>Titanium Ti-38-6-44</td>
<td>0.05</td>
<td>0.30</td>
<td>balance</td>
<td>0.0200</td>
<td>0.03</td>
<td>0.12</td>
<td>0.10</td>
<td>7.5–8.5</td>
<td>3.5–4.5</td>
<td>3.5–4.5</td>
<td>0.15</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>R55111</td>
<td>32</td>
<td>Titanium Ti-5-1-1-1</td>
<td>0.08</td>
<td>0.25</td>
<td>balance</td>
<td>0.0125</td>
<td>0.03</td>
<td>0.11</td>
<td>0.6–1.4</td>
<td>0.6–1.4</td>
<td>0.6–1.40</td>
<td>0.14</td>
<td>0.1 0.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A All reported values are maximums, unless a range is specified.
B A residual is an element present in a metal or an alloy in small quantities inherent to the manufacturing process but not added intentionally. Residual elements need not be reported unless a report is specifically required by the purchaser.
C Ruthenium and Palladium, or both, may be added to Grade 19 for enhanced corrosion resistance as negotiated between purchaser and vendor. Chemical analysis is not required unless specifically negotiated.
4. Materials and Manufacture

4.1 Materials:

4.1.1 The nuts shall be manufactured from material having a chemical composition conforming to the requirements in Table 2 and capable of developing the required mechanical properties for the specified alloy in the finished fastener.

4.1.2 The starting condition of the raw material shall be at the discretion of the fastener manufacturer but shall be such that the finished products conform to all the specified requirements.

4.2 Manufacture:

4.2.1 Forming—Unless otherwise specified, the nuts shall be hot pressed, cold formed, or machined from suitable material at the option of the manufacturer.

4.2.2 Condition—Except as provided in 4.2.3, the nuts shall be furnished in the condition specified below:

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Mechanical Property Marking</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper (all alloys)</td>
<td>As formed or stress relieved at manufacturer's option</td>
<td></td>
</tr>
<tr>
<td>Nickel alloys 400 and 405</td>
<td>As formed or stress relieved at manufacturer's option</td>
<td></td>
</tr>
<tr>
<td>Nickel alloy 500</td>
<td>Solution annealed and aged</td>
<td></td>
</tr>
<tr>
<td>Aluminum alloys:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2024-T4</td>
<td></td>
<td>Solution treated and naturally aged</td>
</tr>
<tr>
<td>6061-T6</td>
<td></td>
<td>Solution treated and artificially aged</td>
</tr>
<tr>
<td>6262-T9</td>
<td></td>
<td>Solution treated, artificially aged, and cold worked</td>
</tr>
<tr>
<td>Titanium 625</td>
<td></td>
<td>As formed</td>
</tr>
</tbody>
</table>

4.2.3 Stress Relieving—When required, stress relieving shall be specified by the purchaser for all copper alloys and nickel alloys 400 and 405.

5. Chemical Composition

5.1 Chemical Composition—The nuts shall conform to the chemical composition specified in Table 1 for the specified alloy.

5.2 Manufacturer’s Analysis:

5.2.1 Except as provided in 5.2.2, when test reports are required on the inquiry or purchase order (3.1.8), the manufacturer shall make individual analyses of randomly selected finished nuts from the product to be shipped and report the results to the purchaser. Alternatively, if heat and lot identities have been maintained, the analysis of the raw material from which the nuts have been manufactured may be reported instead of product analysis.

5.2.2 For aluminum nuts, instead of 5.2.1, the manufacturer may furnish a certificate of conformance certifying compliance with the chemical composition specified in Table 1.

5.3 Product Analysis:

5.3.1 Product analyses may be made by the purchaser from finished products representing each lot. The chemical composition thus determined shall conform to the requirements in Table 1.

5.3.2 In the event of disagreement, a referee chemical analysis of samples from each lot shall be made in accordance with 12.1 and 13.1.

6. Mechanical Properties

6.1 The nuts shall be tested in accordance with the mechanical testing requirements for the applicable type and shall meet the mechanical requirements in Table 2 for the specified alloy.

6.2 Where both proof load and hardness tests are performed, the proof load test results shall take precedence for acceptance purposes.

7. Dimensions

7.1 Nuts—Unless otherwise specified, the dimensions of nuts shall be in accordance with the requirements of ASME B8.2.2.

7.2 Threads—Unless otherwise specified, the nuts shall have Class 6H threads in accordance with ASME B1.1.

### Table 2: Mechanical Property Requirements

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Mechanical Property Marking</th>
<th>Hardness, min A</th>
<th>Proof Stress, min, ksi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu 110</td>
<td>F 467A</td>
<td>65 HRF</td>
<td>30</td>
</tr>
<tr>
<td>Cu 270</td>
<td>F 467B</td>
<td>55 HRF</td>
<td>60</td>
</tr>
<tr>
<td>Cu 462</td>
<td>F 467C</td>
<td>65 HRB</td>
<td>50</td>
</tr>
<tr>
<td>Cu 464</td>
<td>F 467D</td>
<td>55 HRB</td>
<td>50</td>
</tr>
<tr>
<td>Cu 510</td>
<td>F 467E</td>
<td>60 HRB</td>
<td>60</td>
</tr>
<tr>
<td>Cu 613</td>
<td>F 467F</td>
<td>70 HRB</td>
<td>80</td>
</tr>
<tr>
<td>Cu 614</td>
<td>F 467G</td>
<td>70 HRB</td>
<td>75</td>
</tr>
<tr>
<td>Cu 630</td>
<td>F 467H</td>
<td>85 HRB</td>
<td>100</td>
</tr>
<tr>
<td>Cu 642</td>
<td>F 467J</td>
<td>75 HRB</td>
<td>75</td>
</tr>
<tr>
<td>Cu 651</td>
<td>F 467K</td>
<td>75 HRB</td>
<td>70</td>
</tr>
<tr>
<td>Cu 655</td>
<td>F 467L</td>
<td>60 HRB</td>
<td>50</td>
</tr>
<tr>
<td>Cu 661</td>
<td>F 467M</td>
<td>75 HRB</td>
<td>70</td>
</tr>
<tr>
<td>Cu 675</td>
<td>F 467N</td>
<td>60 HRB</td>
<td>55</td>
</tr>
<tr>
<td>Cu 710</td>
<td>F 467P</td>
<td>50 HRB</td>
<td>45</td>
</tr>
<tr>
<td>Cu 715</td>
<td>F 467R</td>
<td>60 HRB</td>
<td>55</td>
</tr>
<tr>
<td>Ni 335</td>
<td>F 467S</td>
<td>20 HRC</td>
<td>115</td>
</tr>
<tr>
<td>Ni 276</td>
<td>F 467T</td>
<td>20 HRC</td>
<td>110</td>
</tr>
<tr>
<td>Ni 400</td>
<td>F 467U</td>
<td>75 HRB</td>
<td>80</td>
</tr>
<tr>
<td>Ni 405</td>
<td>F 467V</td>
<td>60 HRB</td>
<td>70</td>
</tr>
<tr>
<td>Ni 500</td>
<td>F 467W</td>
<td>24 HRC</td>
<td>130</td>
</tr>
<tr>
<td>Ni 625</td>
<td>F 467AC</td>
<td>85 HRB-35 HRC</td>
<td>60</td>
</tr>
<tr>
<td>Ni 686 Grade 1</td>
<td>F 467BN</td>
<td>21 HRC</td>
<td>85</td>
</tr>
<tr>
<td>Ni 686 Grade 2</td>
<td>F 467CN</td>
<td>23 HRC</td>
<td>125</td>
</tr>
<tr>
<td>Ni 686 Grade 3</td>
<td>F 467DN</td>
<td>25 HRC</td>
<td>150</td>
</tr>
<tr>
<td>Al 2024-T4</td>
<td>F 467X</td>
<td>70 HRB</td>
<td>55</td>
</tr>
<tr>
<td>Al 6061-T6</td>
<td>F 467Y</td>
<td>40 HRB</td>
<td>40</td>
</tr>
<tr>
<td>Al 6262-T9</td>
<td>F 467Z</td>
<td>60 HRB</td>
<td>52</td>
</tr>
<tr>
<td>Ti 1</td>
<td>F 467AT</td>
<td>140 HV</td>
<td>40</td>
</tr>
<tr>
<td>Ti 2</td>
<td>F 467BT</td>
<td>150 HV</td>
<td>55</td>
</tr>
<tr>
<td>Ti 4</td>
<td>F 467CT</td>
<td>200 HV</td>
<td>85</td>
</tr>
<tr>
<td>Ti 5</td>
<td>F 467DT</td>
<td>30 HRC</td>
<td>135</td>
</tr>
<tr>
<td>Ti 7</td>
<td>F 467ET</td>
<td>160 HV</td>
<td>55</td>
</tr>
<tr>
<td>Ti-19</td>
<td>F 467FT</td>
<td>24 HRC</td>
<td>120</td>
</tr>
<tr>
<td>Ti 23</td>
<td>F 467GT</td>
<td>25 HRC</td>
<td>125</td>
</tr>
<tr>
<td>Ti-5-1-1-1</td>
<td>F 467HT</td>
<td>24 HRC</td>
<td>105</td>
</tr>
</tbody>
</table>

A For aluminum and titanium alloys hardness values are for information only.

B Aluminum alloy 2024-T4 shall be supplied in naturally aged condition. This material is not recommended for nuts in sizes greater than ¼ (0.250) in.
8. Workmanship, Finish, and Appearance

8.1 Workmanship—Nuts shall have a workmanlike finish free of injurious burrs, seams, laps, irregular surfaces, and other imperfections affecting serviceability.

8.2 Finish—Unless otherwise specified, the nuts shall be furnished without any additive chemical or metallic finish.

9. Sampling

9.1 A lot, for the purposes of selecting test specimens, shall consist of not more than 100,000 pieces offered for inspection at one time having the following common characteristics:

9.1.1 One type of item,
9.1.2 Same alloy and temper, and
9.1.3 One nominal diameter and thread series.

10. Number of Tests and Retests

10.1 Normal Testing—The requirements of this specification shall be met in continuous mass production for stock (see Table 3). The manufacturer shall make sample inspections as specified below to ensure that the product conforms to the specified requirements. When tests of individual shipments are required, Supplementary Requirement S 2 shall be specified.

11. Significance of Numerical Limits

11.1 For purposes of determining compliance with the specified limits for requirements of the properties listed in this specification, an observed value or calculated value shall be specified limits for requirements of the properties listed in this specification. When a test value is outside the range of the requirement, the test value shall be deemed to be the average of the values obtained, which shall be rounded in accordance with Practice E 29.

12. Test Specimens

12.1 Chemical Tests—When required, samples for chemical analysis shall be taken in accordance with Practice E 55 by drilling, sawing, milling, turning, clipping, or such other methods capable of producing representative samples.

12.2 Mechanical Tests:

12.2.1 Nuts shall be tested in full section.

12.2.2 The hardness shall be determined on the top or bottom face of the nut.

13. Test Methods

13.1 Chemical Analysis—When required, the chemical composition shall be determined by any recognized commercial test method. In the event of disagreement, the following test methods shall be used for referee purposes.

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>E 53, E 54, E 62, E 75, E 478</td>
</tr>
<tr>
<td>Aluminum</td>
<td>E 34, E 101, 8a E 227</td>
</tr>
<tr>
<td>Nickel</td>
<td>E 38, E 76, E 354</td>
</tr>
<tr>
<td>Titanium</td>
<td>E 120, E 1409</td>
</tr>
</tbody>
</table>

13.2 Mechanical:

13.2.1 The proof load or proof stress tests shall be determined in accordance with the appropriate methods of Test Methods F 606. Loads to be determined using Table 2 and Table 4.

13.2.2 The hardness shall be determined in accordance with Test Methods E 18 and E 92. For sizes ¼ (0.250) to ½ (0.4375) in. one reading shall be taken. For sizes ½ (0.500) in. and larger the hardness shall be the average of four readings located 90° to one another.

14. Inspection

14.1 When specified on the inquiry or purchase order, the product shall be subject to inspection by the purchaser at the place of manufacture prior to shipment. The inspector representing the purchaser shall have controlled entry only to those parts of the manufacturer’s operations that concern the manufacture of the ordered product and only when and where work on the contract of the purchaser is being performed. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the product is being furnished in accordance with this specification. All inspections and tests shall be conducted so as not to interfere unnecessarily with the operations of the manufacturer.

15. Rejection and Rehearing

15.1 Unless otherwise specified, any rejection based on tests specified herein and made by the purchaser shall be reported to the manufacturer as soon as practical after receipt of the product by the purchaser.

16. Certification and Test Reports

16.1 Certificate of Compliance—When specified in the contract or purchase order, the manufacturer shall furnish certification that the product was manufactured and tested in accordance with this specification and conforms to all specified requirements.

16.2 Test Reports—When “Shipment Lot Testing” in accordance with Supplementary Requirement S 2 is specified in the contract or purchase order, the manufacturer shall furnish a test report showing the results of the mechanical tests for each lot shipped.

<table>
<thead>
<tr>
<th>TABLE 3 Mechanical Test Requirements for Nuts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Hardness</td>
</tr>
<tr>
<td>Jam, slotted, and castle nuts</td>
</tr>
<tr>
<td>All other nuts</td>
</tr>
<tr>
<td>over 120</td>
</tr>
</tbody>
</table>

^A Mandatory tests.
17. Product, Packaging and Package Marking

17.1 Individual Nuts—All products shall be marked with a symbol identifying the manufacturer. In addition, they shall be marked with the alloy/mechanical property marking specified in Table 1. The marking shall be raised or depressed at the option of the manufacturer.

17.2 Packaging:

17.2.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

17.2.2 When special packaging requirements are required by the purchaser, they shall be defined at the time of inquiry and order.

17.3 Package Marking—Each shipping unit shall include or be plainly marked with the following:

- 17.3.1 ASTM designation,
- 17.3.2 Alloy number,
- 17.3.3 Alloy/mechanical property marking,
- 17.3.4 Size,
- 17.3.5 Name and brand or trademark of the manufacturer,
- 17.3.6 Number of pieces,
- 17.3.7 Country of origin, and
- 17.3.8 Purchase order number.

18. Keywords

18.1 general use; nonferrous; nuts

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Stress Corrosion Requirements, Copper Alloys

S1.1 Copper alloy fasteners shall exhibit no evidence of cracking after immersion for 30 min in an aqueous solution of mercurous nitrate when tested in accordance with Test Method B 154.

S1.1.1 Warning—Mercury is a definite health hazard and equipment for the detection and removal of mercury vapor produced in volatilization is recommended. The use of rubber gloves in testing is advisable.
S2. Shipment Lot Testing

S2.1 When Supplementary Requirement S2 is specified on the order (3.1.6), the manufacturer shall make sample tests on the individual lots for shipment to ensure that the product conforms to the specified requirements.

S2.2 The manufacturer shall make an analysis of a randomly selected finished nut from each lot of product to be shipped. Heat or lot control shall be maintained. The analysis of the starting material from which the nuts have been manufactured may be reported in place of the product analysis.

S2.3 The manufacturer shall perform mechanical property tests in accordance with this specification and Guide F 1470 on the individual lots for shipment.

S2.4 The manufacturer shall furnish a test report for each lot in the shipment showing the actual results of the chemical analysis and mechanical property tests performed in accordance with Supplementary Requirement S2.

S3. Dye Penetrant Inspection

S3.1 When dye penetrant inspection is specified on the purchase order, the nuts shall be tested in accordance with Practice E 165 or other mutually acceptable procedures and shall conform to acceptance criteria as mutually agreed upon between the purchaser and the manufacturer.

S4. Heat Control (Alloys 400, 405, and 500 Only)

S4.1 When Supplementary Requirement S4 is specified on the inquiry or order, the manufacturer shall control the product by heat analysis and identify the finished product in each shipment by the actual heat number.

S4.2 When Supplementary Requirement S4 is specified on the inquiry and order, Supplementary Requirement S2 shall be considered automatically invoked with the addition that the heat analysis shall be reported to the purchaser on the test reports.

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Standard Specification for Nonferrous Nuts for General Use [Metric]\(^1\)

This standard is issued under the fixed designation F 467M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (\(\epsilon\)) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope
1.1 This specification covers the requirements for commercial wrought nonferrous nuts in nominal thread diameters M6 to M36 inclusive in a number of alloys in common use and intended for general service applications.

1.2 Applicable bolts, cap screws, and studs for use with nuts covered by this specification are covered by Specification F 468M.

Note 1—This specification is the metric companion of Specification F 467.

2. Referenced Documents

2.1 ASTM Standards:
B 154 Test Method for Mercurous Nitrate Test for Copper and Copper Alloys\(^2\)
B 446 Specification for Nickel-Chromium-Molybdenum-Columbium-Alloy (UNS N06625), Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219), and Nickel-Chromium-Molybdenum-Tungsten Alloy (UNS N06650) Rod and Bar\(^3\)
D 3951 Practice for Commercial Packaging\(^4\)
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials\(^5\)
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications\(^6\)
E 34 Test Methods for Chemical Analysis of Aluminum and Aluminum Base Alloys\(^7\)
E 38 Methods for Chemical Analysis of Nickel-Chromium and Nickel-Chromium-Iron Alloys\(^8\)
E 53 Test Methods for Determination of Copper in Unalloyed Copper by Gravimetry\(^7\)
E 54 Test Methods for Chemical Analysis of Special Brasses and Bronzes\(^9\)
E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition\(^7\)
E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)\(^7\)
E 75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys\(^7\)
E 76 Test Methods for Chemical Analysis of Nickel–Copper Alloys\(^7\)
E 92 Test Method for Vickers Hardness of Metallic Materials\(^5\)
E 101 Test Method for Spectrographic Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique\(^10\)
E 120 Test Methods for Chemical Analysis of Titanium and Titanium Alloys\(^7\)
E 165 Practice for Liquid Penetrant Examination\(^11\)
E 227 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique\(^6\)
E 354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys\(^7\)
E 478 Test Methods for Chemical Analysis of Copper Alloys\(^7\)


\(^2\) Annual Book of ASTM Standards, Vol 02.01.
\(^3\) Annual Book of ASTM Standards, Vol 02.04.
\(^5\) Annual Book of ASTM Standards, Vol 03.01.
\(^7\) Annual Book of ASTM Standards, Vol 03.05.

\(^8\) Discontinued; see 1988 Annual Book of ASTM Standards, Vol 03.05. Replaced by E 350.
\(^9\) Discontinued; see 2001 Annual Book of ASTM Standards, Vol 03.05.
\(^10\) Discontinued; see 1995 Annual Book of ASTM Standards, Vol 03.05.
\(^11\) Annual Book of ASTM Standards, Vol 03.03.
3. Ordering Information

3.1 Orders for nuts under this specification shall include the following information:

3.1.1 Quantity (numbers of pieces of each item and size);
3.1.2 Name of item;
3.1.3 Nominal thread diameter and thread pitch;
3.1.4 Alloy number (Table 1);
3.1.5 Stress relieving, if required (4.2.3);
3.1.6 “Shipment lot” testing, as required (Section 9);
3.1.7 Source inspection, if required (Section 14);
3.1.8 Certificate of compliance or test report, if required (Section 16);
3.1.9 Additional requirements, if any, to be specified on the purchase order (4.2.1, 7.2, 8.2, 11.1, and 12.1);
3.1.10 Supplementary requirements, if any; and
3.1.11 ASTM specification and year of issue.

Note 2—A typical ordering description is as follows: 10,000 pieces, Hex Nut, M8 × 1.25 Alloy 270, Furnish Certificate of Compliance, Supplementary Requirement S1, ASTM Specification F 467M – XX.

4. Materials and Manufacture

4.1 Materials:

4.1.1 The nuts shall be manufactured from material having a chemical composition conforming to the requirements in Table 1 and capable of developing the required mechanical properties for the specified alloy in the nut.

4.1.2 The starting condition of the raw material shall be at the discretion of the fastener manufacturer but shall be such that the nuts conform to all the specified requirements.

4.2 Manufacture:

4.2.1 Forming—Unless otherwise specified, the nuts shall be hot pressed, cold formed, or machined from suitable material at the option of the manufacturer.

4.2.2 Condition—Except as provided in 4.2.3, the nuts shall be furnished in the condition specified below:

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper (all alloys)</td>
<td>As formed or stress relieved at manufacturer’s option</td>
</tr>
<tr>
<td>Nickel alloys 400 and 405</td>
<td>As formed or stress relieved at manufacturer’s option</td>
</tr>
<tr>
<td>Nickel alloy 500</td>
<td>Solution annealed and aged</td>
</tr>
<tr>
<td>Aluminum alloys:</td>
<td></td>
</tr>
<tr>
<td>2024-T4</td>
<td>Solution treated and naturally aged</td>
</tr>
<tr>
<td>6061-T6</td>
<td>Solution treated and artificially aged</td>
</tr>
<tr>
<td>6262-T9</td>
<td>Solution treated, artificially aged, and cold worked</td>
</tr>
<tr>
<td>Titanium</td>
<td>As formed</td>
</tr>
</tbody>
</table>

4.2.3 Stress Relieving—When required, stress relieving shall be specified by the purchaser for all copper alloys and nickel alloys 400 and 405.

5. Chemical Composition

5.1 Chemical Composition—The nuts shall conform to the chemical composition specified in Table 1 for the specified alloy.

5.2 Manufacturer’s Analysis:

5.2.1 Except as provided in 5.2.2, when test reports are required on the inquiry or purchase order (3.1.8), the manufacturer shall make individual analyses of randomly selected nuts from the product to be shipped and report the results to the purchaser. Alternatively, if heat and lot identities have been maintained, the analysis of the raw material from which the nuts have been manufactured may be reported instead of product analysis.

5.2.2 For aluminum nuts, instead of 5.2.1, the manufacturer may furnish a certificate of conformance certifying compliance with the chemical composition specified in Table 1.

5.3 Product Analysis:

5.3.1 Product analyses may be made by the purchaser from nuts representing each lot. The chemical composition thus determined shall conform to the requirements in Table 1.

5.3.2 In the event of disagreement, a referee chemical analysis of samples from each lot shall be made in accordance with 11.1 and 12.1.
<table>
<thead>
<tr>
<th>UNS Designation Number</th>
<th>Alloy</th>
<th>General Name</th>
<th>Aluminum, min</th>
<th>Copper, %</th>
<th>Iron, max</th>
<th>Manganese, max</th>
<th>Nickel, max</th>
<th>Phosphorus, max</th>
<th>Silicon, max</th>
<th>Lead, max</th>
<th>Tin</th>
<th>Arsenic, max</th>
</tr>
</thead>
<tbody>
<tr>
<td>C11000</td>
<td>110</td>
<td>ETP copper</td>
<td>99.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C27000</td>
<td>270</td>
<td>brass</td>
<td>63.0–68.5</td>
<td>0.07</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C46200</td>
<td>462</td>
<td>naval brass</td>
<td>62.0–65.0</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C46400</td>
<td>464</td>
<td>naval brass</td>
<td>59.0–62.0</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C51000</td>
<td>510</td>
<td>phosphor bronze</td>
<td>balance</td>
<td>0.10</td>
<td></td>
<td></td>
<td>0.03–0.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C61400</td>
<td>614</td>
<td>aluminum bronze</td>
<td>6.0–8.0</td>
<td>88.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.5–3.5</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C63000</td>
<td>630</td>
<td>aluminum bronze</td>
<td>9.0–11.0</td>
<td>78.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.0–4.0</td>
<td>1.5</td>
<td>4.0–5.5</td>
<td>0.25 max</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C64200</td>
<td>642</td>
<td>aluminum silicon bronze</td>
<td>6.3–7.6</td>
<td>88.65&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.30</td>
<td>0.10</td>
<td>0.25</td>
<td></td>
<td>1.5–2.2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.50</td>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td>C65100</td>
<td>651</td>
<td>silicon bronze</td>
<td>96.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.8</td>
<td>0.7</td>
<td>0.6</td>
<td></td>
<td></td>
<td>0.8–2.0</td>
<td>1.5</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>C65500</td>
<td>655</td>
<td>silicon bronze</td>
<td>94.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.8</td>
<td>1.5</td>
<td>0.6</td>
<td></td>
<td></td>
<td>2.8–3.8</td>
<td>1.5</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>C66100</td>
<td>661</td>
<td>silicon bronze</td>
<td>94.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.25</td>
<td>1.5</td>
<td>2.8–3.5</td>
<td>1.5</td>
<td></td>
<td>0.20–0.8</td>
<td>0.5–1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C67500</td>
<td>675</td>
<td>manganese bronze</td>
<td>0.25 max</td>
<td>57.0–60.0</td>
<td>0.8–2.0</td>
<td>0.05–0.5</td>
<td></td>
<td></td>
<td>balance</td>
<td>0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C71000</td>
<td>710</td>
<td>cupro-nickel</td>
<td>74.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.60</td>
<td>1.00</td>
<td>19.0–23.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td>1.00</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C71500</td>
<td>715</td>
<td>cupro-nickel</td>
<td>65.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.40–0.7</td>
<td>1.00</td>
<td>29.0–33.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td>1.00</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Elements shown as balance shall be arithmetically computed by deducting the sum of the other named elements from 100.

<sup>b</sup> Minimum content of copper plus all other elements with specified limits shall be 99.5 %.

<sup>c</sup> An alloy containing as high as 2.6 % silicon is acceptable provided the sum of all the elements other than copper, silicon, and iron does not exceed 0.30 %. 
<table>
<thead>
<tr>
<th>UNS Designation Number</th>
<th>Alloy</th>
<th>General Name</th>
<th>Aluminum, max</th>
<th>Carbon, max</th>
<th>Chromium, max</th>
<th>Copper, max</th>
<th>Iron, max</th>
<th>Manganese, max</th>
<th>Nickel&lt;sup&gt;A&lt;/sup&gt;</th>
<th>Phosphorus, max</th>
<th>Silicon, max</th>
<th>Titanium, max</th>
<th>Cobalt, max</th>
<th>Molybdenum, max</th>
<th>Sulfur, max</th>
<th>Vanadium, max</th>
<th>Tungsten, max</th>
</tr>
</thead>
<tbody>
<tr>
<td>N10001</td>
<td>335</td>
<td>Ni-Mo</td>
<td>0.05</td>
<td>1.0 max</td>
<td>4.0–6.0</td>
<td>1.0 balance</td>
<td>balance</td>
<td>0.025</td>
<td>1.00</td>
<td>2.50</td>
<td>26.0–30.0</td>
<td>0.030</td>
<td>0.2–0.4</td>
<td>3.0–4.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N10276</td>
<td>276</td>
<td>Ni-Mo-Cr</td>
<td>0.02</td>
<td>14.5–16.5</td>
<td>4.0–7.0</td>
<td>1.00 balance</td>
<td>balance</td>
<td>0.040</td>
<td>0.08</td>
<td>2.50</td>
<td>15.0–17.0</td>
<td>0.030</td>
<td>0.35 max</td>
<td>3.0–4.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N04400</td>
<td>400</td>
<td>Ni-Cu Class A</td>
<td>0.3</td>
<td>balance</td>
<td>balance</td>
<td>2.0</td>
<td>2.0</td>
<td>63.0–70.0</td>
<td>0.5</td>
<td>0.08</td>
<td>1.00</td>
<td>0.024</td>
<td>0.025–0.060</td>
<td>0.01</td>
<td>3.2–4.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N04405</td>
<td>405</td>
<td>Ni-Cu Class B</td>
<td>0.3</td>
<td>balance</td>
<td>balance</td>
<td>2.0</td>
<td>1.5</td>
<td>63.0–70.0</td>
<td>0.5</td>
<td>0.08</td>
<td>0.02–0.25</td>
<td>15.0–17.0</td>
<td>0.02 max</td>
<td>3.0–4.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N05500</td>
<td>500</td>
<td>Ni-Cu-Al</td>
<td>0.25</td>
<td>2.30–3.15</td>
<td>0.25</td>
<td>2.0</td>
<td>1.5</td>
<td>63.0–70.0</td>
<td>0.5</td>
<td>0.08</td>
<td>0.02–0.25</td>
<td>15.0–17.0</td>
<td>0.02 max</td>
<td>3.0–4.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N06625</td>
<td>625&lt;sup&gt;C&lt;/sup&gt;</td>
<td>Ni-Cr-Mo-Cb</td>
<td>0.010</td>
<td>20.0–23.0</td>
<td>5.0 max</td>
<td>0.05</td>
<td>0.5</td>
<td>58.0 min</td>
<td>0.015</td>
<td>0.40 max</td>
<td>1.00 max</td>
<td>8.0–10.0</td>
<td>0.015</td>
<td>3.2–4.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N06686</td>
<td>686</td>
<td>Ni-Cr-Mo-W</td>
<td>0.010</td>
<td>19.0–23.0</td>
<td>5.0 max</td>
<td>0.75</td>
<td>balance</td>
<td>0.04 max</td>
<td>0.08 max</td>
<td>0.02–0.25</td>
<td>15.0–17.0</td>
<td>0.02 max</td>
<td>3.0–4.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>A</sup> Elements shown as balance shall be arithmetically computed by deducting the sum of the other named elements from 100.

<sup>B</sup> Cobalt is to be counted as nickel.

<sup>C</sup> Alloy 625 material shall be refined using the electroslag remelting process (ESR), or the vacuum arc remelting process (VAR).
<table>
<thead>
<tr>
<th>UNS Designation Number</th>
<th>Alloy</th>
<th>General Name</th>
<th>Aluminum</th>
<th>Chromium</th>
<th>Copper</th>
<th>Iron, max</th>
<th>Manganese, max</th>
<th>Silicon, max</th>
<th>Titanium, max</th>
<th>Zinc, max</th>
<th>Magnesium</th>
<th>Other Elements, max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>A92024</td>
<td>2024</td>
<td>Aluminum</td>
<td>balance</td>
<td>0.10</td>
<td>3.8–4.9</td>
<td>0.50</td>
<td>0.30–0.9</td>
<td>0.50</td>
<td>0.15</td>
<td>0.25</td>
<td>1.2–1.8</td>
<td>0.05</td>
</tr>
<tr>
<td>A96061</td>
<td>6061</td>
<td>Aluminum</td>
<td>balance</td>
<td>0.04–0.35</td>
<td>0.15–0.40</td>
<td>0.7</td>
<td>0.15</td>
<td>0.40–0.8</td>
<td>0.15</td>
<td>0.25</td>
<td>0.8–1.2</td>
<td>0.05</td>
</tr>
<tr>
<td>A96262</td>
<td>6262</td>
<td>Aluminum</td>
<td>balance</td>
<td>0.04–0.14</td>
<td>0.15–0.40</td>
<td>0.7</td>
<td>0.15</td>
<td>0.40–0.8</td>
<td>0.15</td>
<td>0.25</td>
<td>0.8–1.2</td>
<td>c</td>
</tr>
</tbody>
</table>

Table continued...

^ Analysis shall regularly be made only for the elements specified in this table. If, however, the presence of other elements is suspected or indicated in amounts greater than the specified limits, further analysis shall be made to determine that these elements are not present in excess of the specified limits.

Titanium + zirconium 0.20 %, max.

Lead 0.4–0.7 %; bismuth 0.4–0.7 %.
TABLE 1 Continued
Titanium and Titanium-Base Alloys

<table>
<thead>
<tr>
<th>UNS Designation Number</th>
<th>Alloy General Name</th>
<th>Aluminum, Al</th>
<th>Carbon, C</th>
<th>Iron, Fe</th>
<th>Titanium, Ti</th>
<th>Hydrogen, H</th>
<th>Nitrogen, N</th>
<th>Oxygen, O</th>
<th>Palladium, Pd</th>
<th>Vanadium, V</th>
<th>Chromium, Cr</th>
<th>Molybdenum, Mo</th>
<th>Zirconium, Zr</th>
<th>Tin, Sn</th>
<th>Silicon, Si</th>
<th>Ruthenium, Ru</th>
<th>Residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>R50250 1</td>
<td>Titanium Gr 1</td>
<td>0.10</td>
<td>0.20</td>
<td>balance</td>
<td>0.0125</td>
<td>0.05</td>
<td>0.18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>R50400 2</td>
<td>Titanium Gr 2</td>
<td>0.10</td>
<td>0.30</td>
<td>balance</td>
<td>0.0125</td>
<td>0.05</td>
<td>0.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>R50700 4</td>
<td>Titanium Gr 4</td>
<td>0.10</td>
<td>0.50</td>
<td>balance</td>
<td>0.0125</td>
<td>0.07</td>
<td>0.40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>R56400 5</td>
<td>Titanium Gr 5</td>
<td>5.5–6.75</td>
<td>0.10</td>
<td>0.40</td>
<td>balance</td>
<td>0.0125</td>
<td>0.05</td>
<td>0.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.5–4.5</td>
</tr>
<tr>
<td>R56401 23</td>
<td>Titanium Ti-6Al-4V ELI</td>
<td>5.5–6.5</td>
<td>0.08</td>
<td>0.25</td>
<td>balance</td>
<td>0.0125</td>
<td>0.05</td>
<td>0.13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.5–4.5</td>
</tr>
<tr>
<td>R52400 7</td>
<td>Titanium Gr 7</td>
<td>0.10</td>
<td>0.30</td>
<td>balance</td>
<td>0.0125</td>
<td>0.05</td>
<td>0.25</td>
<td>0.12-0.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>R59640 19</td>
<td>Titanium Ti-38-6-44</td>
<td>3.0–4.0</td>
<td>0.05</td>
<td>0.30</td>
<td>balance</td>
<td>0.0200</td>
<td>0.03</td>
<td>0.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7.5–8.5</td>
</tr>
<tr>
<td>R55111 32</td>
<td>Titanium Ti-5-1-1-1</td>
<td>4.5–5.5</td>
<td>0.08</td>
<td>0.25</td>
<td>balance</td>
<td>0.0125</td>
<td>0.03</td>
<td>0.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.6–1.4</td>
</tr>
</tbody>
</table>

A All reported values are maximums, unless a range is specified.
B A residual is an element present in a metal or an alloy in small quantities inherent to the manufacturing process but not added intentionally. Residual elements need not be reported unless a report is specifically required by the purchaser.
C Ruthenium and Palladium, or both, may be added to Grade 19 for enhanced corrosion resistance as negotiated between purchaser and vendor. Chemical analysis is not required unless specifically negotiated.
6. Mechanical Properties

6.1 The nuts shall be tested in accordance with the mechanical testing requirements for the applicable type and shall meet the mechanical requirements in Table 2 for the specified alloy.

6.2 Where both proof load and hardness tests are performed, the proof load test results shall take precedence for acceptance purposes.

7. Dimensions

7.1 Nuts—Unless otherwise specified, the dimensions of nuts shall be in accordance with the requirements of ASME B18.2.4.1M.

7.2 Threads—Unless otherwise specified, the nuts shall have threads in accordance with ASME B1.13M, tolerance Class 6H.

8. Workmanship, Finish, and Appearance

8.1 Workmanship—Nuts shall have a workmanlike finish free of injurious burrs, seams, laps, irregular surfaces, and other imperfections affecting serviceability.

8.2 Finish—Unless otherwise specified, the nuts shall be furnished without any additive chemical or metallic finish.

### TABLE 2 Mechanical Property Requirements

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Mechanical Property Marking</th>
<th>Hardness, min⁴</th>
<th>Proof Stress, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu 110</td>
<td>F 467MA</td>
<td>65 HRF</td>
<td>205</td>
</tr>
<tr>
<td>Cu 270</td>
<td>F 467MB</td>
<td>55 HRF</td>
<td>415</td>
</tr>
<tr>
<td>Cu 462</td>
<td>F 467MC</td>
<td>65 HRB</td>
<td>345</td>
</tr>
<tr>
<td>Cu 464</td>
<td>F 467MD</td>
<td>55 HRB</td>
<td>345</td>
</tr>
<tr>
<td>Cu 510</td>
<td>F 467ME</td>
<td>60 HRB</td>
<td>415</td>
</tr>
<tr>
<td>Cu 614</td>
<td>F 467MG</td>
<td>70 HRB</td>
<td>520</td>
</tr>
<tr>
<td>Cu 630</td>
<td>F 467MH</td>
<td>85 HRB</td>
<td>690</td>
</tr>
<tr>
<td>Cu 642</td>
<td>F 467MJ</td>
<td>75 HRB</td>
<td>520</td>
</tr>
<tr>
<td>Cu 651</td>
<td>F 467MK</td>
<td>75 HRB</td>
<td>485</td>
</tr>
<tr>
<td>Cu 655</td>
<td>F 467ML</td>
<td>60 HRB</td>
<td>345</td>
</tr>
<tr>
<td>Cu 661</td>
<td>F 467MM</td>
<td>75 HRB</td>
<td>485</td>
</tr>
<tr>
<td>Cu 675</td>
<td>F 467MN</td>
<td>60 HRB</td>
<td>380</td>
</tr>
<tr>
<td>Cu 710</td>
<td>F 467MP</td>
<td>50 HRB</td>
<td>310</td>
</tr>
<tr>
<td>Cu 715</td>
<td>F 467MR</td>
<td>60 HRB</td>
<td>380</td>
</tr>
<tr>
<td>Ni 335</td>
<td>F 467MS</td>
<td>20 HRC</td>
<td>790</td>
</tr>
<tr>
<td>Ni 276</td>
<td>F 467MT</td>
<td>20 HRC</td>
<td>760</td>
</tr>
<tr>
<td>Ni 400</td>
<td>F 467MU</td>
<td>75 HRC</td>
<td>550</td>
</tr>
<tr>
<td>Ni 405</td>
<td>F 467MV</td>
<td>60 HRB</td>
<td>485</td>
</tr>
<tr>
<td>Ni 500</td>
<td>F 467MW</td>
<td>24 HRC</td>
<td>900</td>
</tr>
<tr>
<td>Ni 625</td>
<td>F 467AC</td>
<td>85 HRB-35 HRC</td>
<td>415</td>
</tr>
<tr>
<td>Ni 686 Grade 1</td>
<td>F 467MBN</td>
<td>21 HRC</td>
<td>585</td>
</tr>
<tr>
<td>Ni 686 Grade 2</td>
<td>F 467MCN</td>
<td>23 HRC</td>
<td>860</td>
</tr>
<tr>
<td>Ni 686 Grade 3</td>
<td>F 467MDN</td>
<td>25 HRC</td>
<td>1030</td>
</tr>
<tr>
<td>Al 2024-T4⁴</td>
<td>F 467MX</td>
<td>70 HRB</td>
<td>380</td>
</tr>
<tr>
<td>Al 6061-T6</td>
<td>F 467MY</td>
<td>40 HRB</td>
<td>275</td>
</tr>
<tr>
<td>Al 6262-T9</td>
<td>F 467MZ</td>
<td>60 HRB</td>
<td>360</td>
</tr>
</tbody>
</table>

⁴ For aluminum and titanium alloys hardness values are for information only.

### TABLE 3 Mechanical Test Requirements on Nuts

<table>
<thead>
<tr>
<th>Product</th>
<th>Proof Load, kN</th>
<th>Tests Conducted Using Full-Size Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jam, slotted, and castle nuts</td>
<td>all</td>
<td>¹</td>
</tr>
<tr>
<td>All other nuts</td>
<td>up to 530</td>
<td>. . .</td>
</tr>
<tr>
<td>All other nuts</td>
<td>over 530</td>
<td>. . .</td>
</tr>
</tbody>
</table>

Tests in accordance with section 11.2.2 12.2.1

¹ Proof load of nut equals proof stress (MPa) multiplied by stress area (mm²).
² Mandatory tests.
13. Test Methods

13.1 Chemical Analysis—When required, the chemical composition shall be determined by any recognized commercial test method. In the event of disagreement, the following test methods shall be used for referee purposes.

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>E 53, E 54, E 62, E 75, E 478</td>
</tr>
<tr>
<td>Aluminum</td>
<td>E 34, E 101, E 227</td>
</tr>
<tr>
<td>Nickel</td>
<td>E 38, E 76, E 354</td>
</tr>
<tr>
<td>Titanium</td>
<td>E 120, E 1409</td>
</tr>
</tbody>
</table>

13.2 Mechanical:

13.2.1 The proof load test shall be conducted in accordance with the appropriate methods of Test Methods F 606M. Loads to be determined using Table 2 and Table 4.

13.2.2 The hardness shall be determined in accordance with Test Methods E 18 and E 92. For nominal thread diameters M6 to M10, one reading shall be taken. For diameters M12 and larger, the hardness shall be the average of four readings located 90° to one another.

14. Inspection

14.1 When specified on the inquiry or purchase order, the product shall be subject to inspection by the purchaser at the place of manufacture prior to shipment. The inspector representing the purchaser shall have controlled entry only to those parts of the manufacturer’s operations that concern the manufacture of the ordered product and only when and where work on the contract of the purchaser is being performed. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the product is being furnished in accordance with this specification. All inspections and tests shall be conducted so as not to interfere unnecessarily with the operations of the manufacturer.

15. Rejection and Rehearing

15.1 Unless otherwise specified, any rejection based on tests specified herein and made by the purchaser shall be reported to the manufacturer as soon as practical after receipt of the product by the purchaser.

16. Certification and Test Reports

16.1 Certificate of Compliance—When specified in the contract or purchase order, the manufacturer shall furnish certification that the product was manufactured and tested in accordance with this specification and conforms to all specified requirements.

16.2 Test Reports—When “Shipment Lot Testing” in accordance with Supplementary Requirement S2 is specified in the contract or purchase order, the manufacturer shall furnish a test report showing the results of the mechanical tests for each lot shipped.

17. Product, Packaging, and Package Marking

17.1 Individual Nuts—All products shall be marked with a symbol identifying the manufacturer. In addition, they shall be marked with the alloy/mechanical property marking specified in Table 2. The markings shall be raised or depressed at the option of the manufacturer.

17.2 Packaging:

17.2.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

17.2.2 When special packaging requirements are required by the purchaser, they shall be defined at the time of inquiry and order.

17.3 Package Marking—Each shipping unit shall include or be plainly marked with the following:

17.3.1 ASTM specification,
17.3.2 Alloy number,
17.3.3 Alloy/mechanical property marking,
17.3.4 Size,
17.3.5 Name and brand or trademark of the manufacturer,
17.3.6 Number of pieces,
17.3.7 Country of origin, and
17.3.8 Purchase order number.

18. Keywords

18.1 general use; nonferrous; nuts

<table>
<thead>
<tr>
<th>TABLE 4 Tensile Stress Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Nut Diameter and Thread Pitch</td>
</tr>
<tr>
<td>M6 x 1</td>
</tr>
<tr>
<td>M8 x 1.25</td>
</tr>
<tr>
<td>M10 x 1.5</td>
</tr>
<tr>
<td>M12 x 1.75</td>
</tr>
<tr>
<td>M14 x 2</td>
</tr>
</tbody>
</table>

<sup>a</sup> Tensile stress areas are computed using the following formula:

\[ A_s = 0.7854 \left( D - 0.9382P \right)^2 \]

where:

- \( A_s \) = stress area, mm<sup>2</sup>,
- \( D \) = nominal nut diameter (basic major diameter), mm, and
- \( P \) = thread pitch, mm.
SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Stress Corrosion Requirements, Copper Alloys

S1.1 Copper alloy nuts shall exhibit no evidence of cracking after immersion for 30 min in an aqueous solution of mercurous nitrate when tested in accordance with Test Method B 154.

S1.1.1 Warning—Mercury is a definite health hazard and equipment for the detection and removal of mercury vapor produced in volatilization is recommended. The use of rubber gloves in testing is advisable.

S2. Shipment Lot Testing

S2.1 When Supplementary Requirement S2 is specified on the order (3.1.6), the manufacturer shall make sample tests on the individual lots for shipment to ensure that the product conforms to the specified requirements.

S2.2 The manufacturer shall make an analysis of a randomly selected finished nut from each lot of product to be shipped. Heat or lot control shall be maintained. The analysis of the starting material from which the nuts have been manufactured may be reported in place of the product analysis.

S2.3 The manufacturer shall perform mechanical property tests in accordance with this specification and Guide F 1470 on the individual lots for shipment.

S2.4 The manufacturer shall furnish a test report for each lot in the shipment showing the actual results of the chemical analysis and mechanical property tests performed in accordance with Supplementary Requirement S2.

S3. Dye Penetrant Inspection

S3.1 When dye penetrant inspection is specified on the purchase order, the nuts shall be tested in accordance with Practice E 165 or other mutually acceptable procedures and shall conform to acceptance criteria as mutually agreed upon between the purchaser and the manufacturer.

S4. Heat Control (Alloys 400, 405, and 500 Only)

S4.1 When Supplementary Requirement S4 is specified on the inquiry or order, the manufacturer shall control the product by heat analysis and identify the finished product in each shipment by the actual heat number.

S4.2 When Supplementary Requirement S4 is specified on the inquiry and order, Supplementary Requirement S2 shall be considered automatically invoked with the addition that the heat analysis shall be reported to the purchaser on the test reports.

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Standard Specification for
Nonferrous Bolts, Hex Cap Screws, and Studs for General Use

This standard is issued under the fixed designation F 468; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers the requirements for commercial wrought nonferrous bolts, hex cap screws, and studs 0.250 to
1.500 in. inclusive in diameter manufactured from a number of alloys in common use and intended for general service applications.

1.2 Applicable nuts for use with bolts, cap screws, and studs covered by this specification are covered by Specification F 467.

NOTE 1—A complete metric companion to Specification F 468 has been developed—F 468M; therefore no metric equivalents are presented in this
specification.

2. Referenced Documents

2.1 ASTM Standards:
B 154 Test Method for Mercurous Nitrate Test for Copper and Copper Alloys

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States.
B 193 Test Method for Resistivity of Electrical Conductor Materials

B 211 Specification for Aluminum and Aluminum-Alloy Bar, Rod, and Wire

B 446 Specification for Nickel-Chromium-Molybdenum-Columbium-Alloy (UNS N06625), Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219), and Nickel-Chromium-Molybdenum-Tungsten Alloy (UNS N06650) Rod and Bar

B 565 Test Method for Shear Testing of Aluminum and Aluminum-Alloy Rivets and Cold-Heading Wire and Rods

D 3951 Practice for Commercial Packaging

E 8 Test Methods for Tension Testing of Metallic Materials

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 34 Test Methods for Chemical Analysis of Aluminum and Aluminum Base Alloys

E 38 Methods for Chemical Analysis of Nickel-Chromium and Nickel-Chromium-Iron Alloys

E 53 Test Methods for Determination of Copper in Unalloyed Copper by Gravimetry

E 54 Test Methods for Chemical Analysis of Special Brasses and Bronzes

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)

E 75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys

E 76 Test Methods for Chemical Analysis of Nickel-Copper Alloys

E 92 Test Method for Vickers Hardness of Metallic Materials

E 101 Test Method for Spectrographic Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique

E 120 Test Methods for Chemical Analysis of Titanium and Titanium Alloys

E 165 Practice for Liquid Penetrant Examination

E 227 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique

E 354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys

E 478 Test Methods for Chemical Analysis of Copper Alloys

E 1409 Test Method for Determination of Oxygen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique

F 467 Specification for Nonferrous Nuts for General Use

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

2.2 ASME Standards:

ASME B1.1 Unified Inch Screw Threads (UN and UNR Thread Form)

ASME B18.2.1 Square and Hex Bolts and Screws, Including Hex Cap Screws

ASME H35.1 Alloy and Temper Designation Systems for Aluminum

3. Ordering Information

3.1 Orders for fasteners under this specification shall include the following information:

3.1.1 Quantity (number of pieces of each item and size),

3.1.2 Name of item. For silicon bronze alloy 651, state if hex cap screw dimensions or roll thread body diameter are required (see 7.1.2);

3.1.3 Size (diameter, threads per inch, length);

3.1.4 Alloy number (Table 1). For Ti5, state Class A or Class B (Table 1, 6.5, and 6.5.1);

3.1.5 Stress relieving, if required (see 4.2.3);

3.1.6 Shipment lot testing, as required (see Section 10);

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2 Annual Book of ASTM Standards, Vol 02.01.
3 Annual Book of ASTM Standards, Vol 02.03.
4 Annual Book of ASTM Standards, Vol 02.02.
7 Annual Book of ASTM Standards, Vol 03.01.
9 Annual Book of ASTM Standards, Vol 03.05.
10 Discontinued; see 1988 Annual Book of ASTM Standards, Vol 03.05.
12 Discontinued; see 1995 Annual Book of ASTM Standards, Vol 03.05.
13 Annual Book of ASTM Standards, Vol 03.03.
14 Annual Book of ASTM Standards, Vol 01.08.

2
3.1.7 Source inspection, if required (see Section 14);
3.1.8 Certificate of compliance or test report, if required (see Section 16);
3.1.9 Additional requirements, if any, to be specified on the purchase order (see 4.2.1, 4.2.4, 7.3.1, 8.2, 11.1, and 12.1);
3.1.10 Supplementary Requirements, if any; and
3.1.11 ASTM designation and date of issue.

NOTE 2—Example
10 000 pieces, Hex Cap Screw, 0.250 in.-20 × 3.00 in., Alloy 270. Furnish Certificate of Compliance, Supplementary Requirement S1, ASTM F 468-XX.

4. Materials and Manufacture

4.1 Materials:
4.1.1 The bolts, cap screws, and studs shall be manufactured from material having a chemical composition conforming to the requirements in Table 1 and capable of developing the required mechanical properties for the specified alloy in the finished fastener.
4.1.2 The starting condition of the raw material shall be at the discretion of the fastener manufacturer but shall be such that the finished products conform to all of the specified requirements.

4.2 Manufacture:
4.2.1 Forming—Unless otherwise specified, the fasteners shall be cold formed, hot formed, or machined from suitable material, at the option of the manufacturer.
4.2.2 Condition—Except as provided in 4.2.3, the fasteners shall be furnished in the following conditions:

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper (all alloys)</td>
<td>As formed or stress relieved at manufacturer’s option</td>
</tr>
<tr>
<td>Nickel alloys:</td>
<td>As formed or stress relieved at manufacturer’s option</td>
</tr>
<tr>
<td>400 and 405</td>
<td>Solution annealed and aged</td>
</tr>
<tr>
<td>500</td>
<td>Annealed</td>
</tr>
<tr>
<td>625</td>
<td>Solution treated and naturally aged</td>
</tr>
<tr>
<td>Aluminum alloys:</td>
<td>Solution treated and artificially aged</td>
</tr>
<tr>
<td>2024-T4</td>
<td>Solution treated and stabilized</td>
</tr>
<tr>
<td>6061-T6</td>
<td>As formed</td>
</tr>
<tr>
<td>7075-T73</td>
<td></td>
</tr>
<tr>
<td>Titanium</td>
<td></td>
</tr>
</tbody>
</table>

4.2.3 Stress Relieving—When required, stress relieving shall be specified by the purchaser for nickel alloys 400 and 405 and all copper alloys.
4.2.4 Threads—Unless otherwise specified, the threads shall be rolled or cut at the option of the manufacturer.

5. Chemical Composition

5.1 Chemical Composition—The fasteners shall conform to the requirements as to chemical composition prescribed in Table 1 for the specified alloy.

5.2 Manufacturer’s Analysis:
5.2.1 When test reports are required on the inquiry or purchase order (see 3.1.8), the manufacturer shall make individual analyses of randomly selected finished fasteners from the product to be shipped and report the results to the purchaser, except as provided in 5.2.2. Alternatively, if heat and lot identities have been maintained, the analysis of the raw material from which the fasteners have been manufactured may be reported instead of product analysis.
5.2.2 For aluminum fasteners, the manufacturer may furnish instead a certificate of conformance certifying compliance with the chemical composition specified in Table 1.

5.3 Product Analysis:
5.3.1 Product analyses may be made by the purchaser from finished products representing each lot. The chemical composition thus determined shall conform to the requirements in Table 1.
5.3.2 In the event of disagreement, a referee chemical analysis of samples from each lot shall be made in accordance with 11.1 and 12.1.
# TABLE 1 Chemical Requirements

## Composition, %

<table>
<thead>
<tr>
<th>UNS Designation Number</th>
<th>Alloy</th>
<th>General Name</th>
<th>Aluminum, min</th>
<th>Copper, min</th>
<th>Iron, max</th>
<th>Manganese, max</th>
<th>Nickel, max</th>
<th>Phosphorus, max</th>
<th>Silicon</th>
<th>Zinc, max&lt;sup&gt;A&lt;/sup&gt;</th>
<th>Lead, max</th>
<th>Tin</th>
<th>Arsenic, max</th>
</tr>
</thead>
<tbody>
<tr>
<td>C11000</td>
<td>110</td>
<td>ETP copper</td>
<td>99.9</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C27000</td>
<td>270</td>
<td>brass</td>
<td>63.0–68.5</td>
<td>0.07</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C46200</td>
<td>462</td>
<td>naval brass</td>
<td>62.0–65.0</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C46400</td>
<td>464</td>
<td>naval brass</td>
<td>59.0–62.0</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C51000</td>
<td>510</td>
<td>phosphor bronze</td>
<td>balance&lt;sup&gt;A&lt;/sup&gt;</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
<td>0.03–0.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C61300</td>
<td>613</td>
<td>aluminum bronze</td>
<td>6.0–7.5</td>
<td>2.0–3.0</td>
<td>0.10</td>
<td>0.15&lt;sup&gt;C&lt;/sup&gt;</td>
<td>0.015</td>
<td>0.10</td>
<td>0.05</td>
<td>0.01</td>
<td>0.20–0.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C61400</td>
<td>614</td>
<td>aluminum bronze</td>
<td>6.0–8.0</td>
<td>88.0&lt;sup&gt;D&lt;/sup&gt;</td>
<td>1.5–3.5</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C63000</td>
<td>630</td>
<td>aluminum bronze</td>
<td>9.0–11.0</td>
<td>78.0&lt;sup&gt;D&lt;/sup&gt;</td>
<td>2.0–4.0</td>
<td>1.5</td>
<td>4.0–5.5</td>
<td>0.25 max</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C64200</td>
<td>642</td>
<td>aluminum silicon bronze</td>
<td>6.3–7.6</td>
<td>88.65&lt;sup&gt;D&lt;/sup&gt;</td>
<td>0.30</td>
<td>0.10</td>
<td>0.25</td>
<td>1.5–2.2&lt;sup&gt;C&lt;/sup&gt;</td>
<td>0.50</td>
<td>0.05</td>
<td>0.20 max</td>
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<td>C65100</td>
<td>651</td>
<td>silicon bronze</td>
<td>96.0&lt;sup&gt;D&lt;/sup&gt;</td>
<td>0.8</td>
<td>0.7</td>
<td></td>
<td>0.8–2.0</td>
<td>1.5</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C65500</td>
<td>655</td>
<td>silicon bronze</td>
<td>94.8&lt;sup&gt;D&lt;/sup&gt;</td>
<td>0.8</td>
<td>1.5</td>
<td>0.6</td>
<td>2.8–3.8</td>
<td>1.5</td>
<td>0.05</td>
<td></td>
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</tr>
<tr>
<td>C66100</td>
<td>661</td>
<td>silicon bronze</td>
<td>94.0&lt;sup&gt;D&lt;/sup&gt;</td>
<td>0.25</td>
<td>1.5</td>
<td></td>
<td>2.8–3.5</td>
<td>1.5</td>
<td>0.20–0.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C67500</td>
<td>675</td>
<td>manganese bronze</td>
<td>57.0–60.0</td>
<td>0.8–2.0</td>
<td>0.05–0.5</td>
<td></td>
<td></td>
<td></td>
<td>0.20</td>
<td>0.5–1.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C71000</td>
<td>710</td>
<td>cupro-nickel</td>
<td>74.0&lt;sup&gt;D&lt;/sup&gt;</td>
<td>0.60</td>
<td>1.00</td>
<td>19.0–23.0&lt;sup&gt;C&lt;/sup&gt;</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C71500</td>
<td>715</td>
<td>cupro-nickel</td>
<td>65.0&lt;sup&gt;D&lt;/sup&gt;</td>
<td>0.40–0.7</td>
<td>1.00</td>
<td>29.0–33.0&lt;sup&gt;C&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>A</sup> Elements shown as balance shall be arithmetically computed by deducting the sum of the other named elements from 100.

<sup>B</sup> Copper plus specified elements = 99.8 min; copper plus silver = 88.3–91.5.

<sup>C</sup> Cobalt is to be counted as nickel.

<sup>D</sup> Minimum content of copper plus all other elements with specified limits shall be 99.5%.

<sup>D</sup> An alloy containing as high as 2.6% silicon is acceptable provided the sum of all the elements other than copper, silicon, and iron does not exceed 0.30%.
### TABLE 1 Continued

Nickel and Nickel-Base Alloys

<table>
<thead>
<tr>
<th>UNS Designation Number</th>
<th>Alloy</th>
<th>General Name</th>
<th>Aluminum, max</th>
<th>Carbon, max</th>
<th>Chromium, max</th>
<th>Copper&lt;sup&gt;A&lt;/sup&gt;</th>
<th>Iron, max</th>
<th>Manganese, max</th>
<th>Nickel&lt;sup&gt;B&lt;/sup&gt;</th>
<th>Phosphorus, max</th>
<th>Silicon, max</th>
<th>Titanium, max</th>
<th>Cobalt, max</th>
<th>Molybdenum, max</th>
<th>Sulfur, max</th>
<th>Vanadium, max</th>
<th>Tungsten, max</th>
</tr>
</thead>
<tbody>
<tr>
<td>N10001 335 N10276 276</td>
<td>Ni-Mo</td>
<td>0.05 1.0 max</td>
<td>4.0–6.0</td>
<td>1.0 balance</td>
<td>0.025</td>
<td>1.0</td>
<td>2.50</td>
<td>26.0–30.0</td>
<td>0.030</td>
<td>0.2–0.4</td>
<td>0.35 max</td>
<td>3.0–4.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N04400 400 N04405 405</td>
<td>Ni-Cu Class A</td>
<td>0.3 balance</td>
<td>2.5 2.0</td>
<td>0.040 0.085</td>
<td>0.015 0.04 max</td>
<td>0.02–0.25 max</td>
<td>15.0–17.0</td>
<td>0.015</td>
<td>3.2–4.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N06625 625&lt;sup&gt;C&lt;/sup&gt;</td>
<td>Ni-Cu-Mo-Cb</td>
<td>0.010 0.50</td>
<td>0.015 0.30 max</td>
<td>0.02–0.25 max</td>
<td>15.0–17.0</td>
<td>0.02 max</td>
<td>3.0–4.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>A</sup> Elements shown as balance shall be arithmetically computed by deducting the sum of the other named elements from 100.

<sup>B</sup> Cobalt is to be counted as nickel.

<sup>C</sup> Alloy 625 material shall be refined using the electroslag remelting process (ESR), or the vacuum arc remelting process (VAR).
<table>
<thead>
<tr>
<th>UNS Designation Number</th>
<th>Alloy</th>
<th>General Name</th>
<th>Aluminum</th>
<th>Chromium</th>
<th>Copper</th>
<th>Iron, max</th>
<th>Manganese, max</th>
<th>Silicon, max</th>
<th>Titanium, max</th>
<th>Zinc, max</th>
<th>Magnesium</th>
<th>Other Elements, max</th>
</tr>
</thead>
<tbody>
<tr>
<td>A92024</td>
<td>2024</td>
<td>Aluminum 2024</td>
<td>balance</td>
<td>0.10 max</td>
<td>3.8–4.9</td>
<td>0.50</td>
<td>0.30–0.9</td>
<td>0.50</td>
<td>0.15</td>
<td>0.25</td>
<td>1.2–1.8</td>
<td>0.05 0.15</td>
</tr>
<tr>
<td>A96061</td>
<td>6061</td>
<td>Aluminum 6061</td>
<td>balance</td>
<td>0.04–0.35</td>
<td>0.15–0.40</td>
<td>0.7</td>
<td>0.15</td>
<td>0.40–0.8</td>
<td>0.15</td>
<td>0.25</td>
<td>0.8–1.2</td>
<td>0.05 0.15</td>
</tr>
<tr>
<td>A97075</td>
<td>7075</td>
<td>Aluminum 7075</td>
<td>balance</td>
<td>0.18–0.35</td>
<td>1.2–2.0</td>
<td>0.50</td>
<td>0.30</td>
<td>0.40</td>
<td>0.20(^c)</td>
<td></td>
<td>5.1–6.1</td>
<td>2.1–2.9</td>
</tr>
</tbody>
</table>

\(^a\) Analysis shall regularly be made only for the elements specified in this table. If, however, the presence of other elements is suspected or indicated in amounts greater than the specified limits, further analysis shall be made to determine that these elements are not present in excess of the specified limits.  
\(^b\) Elements shown as balance shall be arithmetically computed by deducting the sum of the other named elements from 100.  
\(^c\) Titanium + zirconium 0.20 %, max.  
\(^d\) Titanium + zirconium 0.25 %, max.
### TABLE 1 Continued

Titanium and Titanium-Base Alloys

<table>
<thead>
<tr>
<th>UNS Designation Number</th>
<th>Alloy</th>
<th>General Name</th>
<th>Aluminum, Al</th>
<th>Carbon, C</th>
<th>Iron, Fe</th>
<th>Titanium, Ti</th>
<th>Hydrogen, H</th>
<th>Nitrogen, N</th>
<th>Oxygen, O</th>
<th>Palladium, Pd</th>
<th>Vanadium, V</th>
<th>Chromium, Cr</th>
<th>Molybdenum, Mo</th>
<th>Zirconium, Zr</th>
<th>Tin, Sn</th>
<th>Silicon, Si</th>
<th>Ruthenium, Ru</th>
<th>Residuals&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>R50250</td>
<td>1</td>
<td>Titanium Gr 1</td>
<td>0.10</td>
<td>0.20</td>
<td>balance</td>
<td>0.0125</td>
<td>0.05</td>
<td>0.18</td>
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<td>0.1</td>
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<td>R50400</td>
<td>2</td>
<td>Titanium Gr 2</td>
<td>0.10</td>
<td>0.30</td>
<td>balance</td>
<td>0.0125</td>
<td>0.05</td>
<td>0.25</td>
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<td>0.1</td>
</tr>
<tr>
<td>R50700</td>
<td>4</td>
<td>Titanium Gr 4</td>
<td>0.10</td>
<td>0.50</td>
<td>balance</td>
<td>0.0125</td>
<td>0.07</td>
<td>0.40</td>
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<td></td>
<td>0.1</td>
</tr>
<tr>
<td>R56400</td>
<td>5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Titanium Gr 5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.5–6.75</td>
<td>0.10</td>
<td>0.40</td>
<td>balance</td>
<td>0.0125</td>
<td>0.05</td>
<td>0.20</td>
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<td>3.5–4.5</td>
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<tr>
<td>R56401</td>
<td>23</td>
<td>Titanium Ti-6Al-4V ELI</td>
<td>5.5–6.5</td>
<td>0.08</td>
<td>0.25</td>
<td>balance</td>
<td>0.0125</td>
<td>0.05</td>
<td>0.13</td>
<td></td>
<td>3.5–4.5</td>
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<tr>
<td>R52400</td>
<td>7</td>
<td>Titanium Gr 7</td>
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<td>0.30</td>
<td>balance</td>
<td>0.0125</td>
<td>0.05</td>
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<td>0.12–0.25</td>
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<td>0.1</td>
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<tr>
<td>R58640</td>
<td>19</td>
<td>Titanium Ti-38-6-44</td>
<td>3.0–4.0</td>
<td>0.05</td>
<td>0.30</td>
<td>balance</td>
<td>0.0200</td>
<td>0.03</td>
<td>0.12</td>
<td>0.1&lt;sup&gt;d&lt;/sup&gt;</td>
<td>7.5–8.5</td>
<td>5.5–6.5</td>
<td>3.5–4.5</td>
<td>0.10&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.15</td>
<td></td>
<td></td>
<td>0.1</td>
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<tr>
<td>R55111</td>
<td>32</td>
<td>Titanium Ti-5-1-1-1</td>
<td>4.5–5.5</td>
<td>0.08</td>
<td>0.25</td>
<td>balance</td>
<td>0.0125</td>
<td>0.03</td>
<td>0.11</td>
<td>0.1&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.6–1.4</td>
<td>0.6–1.4</td>
<td>0.6–1.4</td>
<td>0.10&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.15</td>
<td></td>
<td></td>
<td>0.1</td>
</tr>
</tbody>
</table>

<sup>a</sup> All reported values are maximums, unless a range is specified.

<sup>b</sup> A residual is an element present in a metal or an alloy in small quantities inherent to the manufacturing process but not added intentionally. Residual elements need not be reported unless a report is specifically required by the purchaser.

<sup>c</sup> Identical chemical requirements apply to both Class A and B as defined in Table 2 and 6.5.

<sup>d</sup> Ruthenium and palladium, or both, may be added to Grade 19 for enhanced corrosion resistance as negotiated between purchaser and vendor. Chemical analysis is not required unless specifically required by the purchaser.
### TABLE 2 Mechanical Property Requirements

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Mechanical Property Marking</th>
<th>Nominal Thread Diameter, in.</th>
<th>Hardness&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Full-Size Tests&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Machined Specimen Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tensile Strength, ksi</td>
<td>Yield Strength, min, ksi&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cu 110</td>
<td>F 468A</td>
<td>all</td>
<td>65–90 HRF</td>
<td>30–50</td>
<td>10</td>
</tr>
<tr>
<td>Cu 270</td>
<td>F 468B</td>
<td>all</td>
<td>55–80 HRF</td>
<td>60–90</td>
<td>50</td>
</tr>
<tr>
<td>Cu 462</td>
<td>F 468C</td>
<td>all</td>
<td>65–90 HRF</td>
<td>50–80</td>
<td>25</td>
</tr>
<tr>
<td>Cu 464</td>
<td>F 468D</td>
<td>all</td>
<td>55–75 HRF</td>
<td>50–80</td>
<td>15</td>
</tr>
<tr>
<td>Cu 510</td>
<td>F 468E</td>
<td>all</td>
<td>60–95 HRF</td>
<td>60–90</td>
<td>35</td>
</tr>
<tr>
<td>Cu 613</td>
<td>F 468F</td>
<td>{ 0.250–0.500</td>
<td>70–95 HRF</td>
<td>80–110</td>
<td>50</td>
</tr>
<tr>
<td>Cu 614</td>
<td>F 468G</td>
<td>all</td>
<td>70–95 HRF</td>
<td>75–110</td>
<td>45</td>
</tr>
<tr>
<td>Cu 630</td>
<td>F 468H</td>
<td>all</td>
<td>85–100 HRF</td>
<td>100–130</td>
<td>50</td>
</tr>
<tr>
<td>Cu 642</td>
<td>F 468J</td>
<td>all</td>
<td>75–95 HRF</td>
<td>75–110</td>
<td>35</td>
</tr>
<tr>
<td>Cu 651</td>
<td>F 468K</td>
<td>{ 0.250 to 0.750</td>
<td>75–95 HRF</td>
<td>70–100</td>
<td>55</td>
</tr>
<tr>
<td>Cu 655</td>
<td>F 468L</td>
<td>all</td>
<td>60–80 HRF</td>
<td>50–80</td>
<td>20</td>
</tr>
<tr>
<td>Cu 661</td>
<td>F 468M</td>
<td>all</td>
<td>75–95 HRF</td>
<td>70–100</td>
<td>35</td>
</tr>
<tr>
<td>Cu 675</td>
<td>F 468N</td>
<td>all</td>
<td>60–90 HRF</td>
<td>55–85</td>
<td>25</td>
</tr>
<tr>
<td>Cu 710</td>
<td>F 468P</td>
<td>all</td>
<td>50–85 HRF</td>
<td>45–75</td>
<td>15</td>
</tr>
<tr>
<td>Cu 715</td>
<td>F 468R</td>
<td>all</td>
<td>60–95 HRF</td>
<td>55–65</td>
<td>20</td>
</tr>
<tr>
<td>Ni 335</td>
<td>F 468S</td>
<td>all</td>
<td>20–32 HRC</td>
<td>115–145</td>
<td>45</td>
</tr>
<tr>
<td>Ni 276</td>
<td>F 468T</td>
<td>all</td>
<td>20–32 HRC</td>
<td>110–140</td>
<td>45</td>
</tr>
<tr>
<td>Ni 400</td>
<td>F 468U</td>
<td>{ 0.250 to 0.750</td>
<td>75 HRC–25 HRC</td>
<td>80–130</td>
<td>40</td>
</tr>
<tr>
<td>Ni 400 HF&lt;sup&gt;e&lt;/sup&gt;</td>
<td>F 468HF</td>
<td>all</td>
<td>60–95 HRC</td>
<td>70–120</td>
<td>30</td>
</tr>
<tr>
<td>Ni 405</td>
<td>F 468V</td>
<td>all</td>
<td>60 HRC–20 HRC</td>
<td>70–125</td>
<td>30</td>
</tr>
<tr>
<td>Ni 500</td>
<td>F 468W</td>
<td>{ 0.250 to 0.875</td>
<td>24–37 HRC</td>
<td>130–180</td>
<td>90</td>
</tr>
<tr>
<td>Ni 625</td>
<td>F 468AC</td>
<td>all</td>
<td>85 HRC–35 HRC</td>
<td>120</td>
<td>60</td>
</tr>
<tr>
<td>Ni 688</td>
<td>F 468BN</td>
<td>all</td>
<td>23–44 HRC</td>
<td>120–185</td>
<td>400</td>
</tr>
<tr>
<td>Grade 1</td>
<td>F 468BN</td>
<td>all</td>
<td>21–45 HRC</td>
<td>120–165</td>
<td>85</td>
</tr>
<tr>
<td>Grade 2</td>
<td>F 468CN</td>
<td>all</td>
<td>23–47 HRC</td>
<td>135–185</td>
<td>125</td>
</tr>
<tr>
<td>Grade 3</td>
<td>F 468DN</td>
<td>all</td>
<td>25–49 HRC</td>
<td>160–200</td>
<td>150</td>
</tr>
<tr>
<td>Al 2024–T4&lt;sup&gt;g&lt;/sup&gt;</td>
<td>F 468X</td>
<td>all</td>
<td>70–85 HRC</td>
<td>55–70</td>
<td>36</td>
</tr>
<tr>
<td>Al 6061–T6&lt;sup&gt;g&lt;/sup&gt;</td>
<td>F 468Y</td>
<td>all</td>
<td>40–50 HRC</td>
<td>37–52</td>
<td>31</td>
</tr>
<tr>
<td>Al 7075–T73&lt;sup&gt;g&lt;/sup&gt;</td>
<td>F 468Z</td>
<td>all</td>
<td>80–90 HRC</td>
<td>61–76</td>
<td>50</td>
</tr>
<tr>
<td>Titanium&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ti 1</td>
<td>F 468AT</td>
<td>all</td>
<td>140–160 HV</td>
<td>35–70</td>
<td>30</td>
</tr>
<tr>
<td>Ti 2</td>
<td>F 468BT</td>
<td>all</td>
<td>160–180 HV</td>
<td>50–85</td>
<td>45</td>
</tr>
<tr>
<td>Ti 4</td>
<td>F 468CT</td>
<td>all</td>
<td>200–220 HV</td>
<td>80–115</td>
<td>75</td>
</tr>
<tr>
<td>Ti 5 Class A&lt;sup&gt;h&lt;/sup&gt;</td>
<td>F 468DT</td>
<td>all</td>
<td>30–39 HRC</td>
<td>130–165</td>
<td>125</td>
</tr>
<tr>
<td>Ti 5 Class B&lt;sup&gt;h&lt;/sup&gt;</td>
<td>F 468HT</td>
<td>all</td>
<td>30–39 HRC</td>
<td>130–165</td>
<td>125</td>
</tr>
<tr>
<td>Ti 7</td>
<td>F 468ET</td>
<td>all</td>
<td>160–180 HV</td>
<td>50–85</td>
<td>45</td>
</tr>
<tr>
<td>Ti 19</td>
<td>F 468FT</td>
<td>all</td>
<td>24–38 HRC</td>
<td>115–150</td>
<td>115</td>
</tr>
<tr>
<td>Ti 23</td>
<td>F 468GT</td>
<td>all</td>
<td>25–36 HRC</td>
<td>120–165</td>
<td>110</td>
</tr>
<tr>
<td>Ti-5-1-1-1</td>
<td>F 468HT</td>
<td>all</td>
<td>24–38 HRC</td>
<td>105–150</td>
<td>90</td>
</tr>
</tbody>
</table>

<sup>a</sup> Where both tension and hardness tests are performed, the tension tests shall take precedence for acceptance purposes. For aluminum and titanium alloys, hardness tests are for information only. See 6.5.

<sup>b</sup> The yield and tensile strength values for full-size products shall be computed by dividing the yield and maximum tensile load by the stress area for the product diameter and thread pitch as given in table on tensile stress areas.

<sup>c</sup> Yield strength is the stress at which an offset of 0.2 % gage length occurs.

<sup>d</sup> Elongation is determined using a gage length of 4 diameters of test specimen in accordance with Test Methods E 8.

<sup>e</sup> “HF” denotes a hot-formed product.

<sup>f</sup> Aluminum alloy temper designations are in accordance with ANSI H35.1.

<sup>g</sup> Full-size test mechanical properties apply to fasteners with a maximum diameter of 76 mm. Mechanical properties of larger sections shall be negotiated between the material manufacturer and the fastener producer.

<sup>h</sup> Ti 5 Class A requires wedge tensile testing in accordance with 6.6. Ti 5 Class B requires wedge tensile testing in accordance with 6.5.1.
6. Mechanical Properties

6.1 The fasteners shall be tested in accordance with the mechanical testing requirements for the applicable type, length of product, and minimum tensile strength and shall meet the mechanical properties in Table 2 and Table 3 for the specified alloy.

6.2 Fasteners having a length equal to or longer than the "minimum length of product requiring tension testing" as specified in Test Methods F 606 and a breaking load of 120 000 lbf or less shall be tested full size and shall meet the full-size tensile (minimum and maximum) and yield strength properties in Table 2 for the specified alloy.

6.3 Fasteners having a length equal to or longer than the "minimum length of product requiring tension testing" as specified in Test Methods F 606 and a breaking load exceeding 120 000 lbf shall preferably be tested full size and shall meet the full-size tensile (minimum and maximum) and yield strength properties in Table 2. When equipment of sufficient capacity for such tests is not available, or if excessive length of the bolts or stud makes full-size testing impractical, standard round specimens shall be used which shall meet the "machined specimen tests" tensile properties in Table 2. In the event of a discrepancy between full-size and machined specimen tension tests, full-size tests shall be used as the referee method to determine acceptance.

6.4 For all alloys except aluminum and titanium, fasteners that are too short (lengths less than that specified in Test Methods F 606 as the "minimum length of product requiring tension testing"); that have insufficient threads for tension testing (see 11.2), or that have drilled or undersized heads weaker than the thread section, are not subject to tension tests but shall conform to the minimum and maximum hardness in Table 2. Hardness tests are not applicable to aluminum and titanium alloys. When required for aluminum alloys, a shear test shall be performed in accordance with 11.2.2 and 12.2.2. Test results shall conform to the following minimum shear strength requirements: 37 ksi for 2024-T4; 25 ksi for 6061-T6; and 41 ksi for 7075-T73.

6.5 Full-size bolts and cap screws subject to tension tests shall be tested using a wedge under the head. Wedge angles shall be as follows, except for Ti5 Class B which shall use wedge angles as defined in 6.5.1. The wedge shall be 10° for bolts and cap screws of 0.750-in. nominal diameter and less, and 6° for bolts and cap screws over 0.750 in. in diameter. For bolts and cap screws threaded essentially to the head, the wedge angle shall be 6° for sizes 0.750 in. in nominal diameter and less and 4° for sizes over 0.750 in. in diameter.

6.5.1 Ti5 Class B wedge angles shall be 6° for bolts and cap screws of 0.750 in. nominal diameter and less and 4° for bolts and cap screws over 0.750 in. in diameter. For bolts and cap screws threaded essentially to the head, the wedge angle shall be 4° for bolts and cap screws of 0.750 in. nominal diameter and less and 2° for bolts and cap screws over 0.750 in. in diameter.

6.6 Where both tension and hardness tests are performed, the tension test results shall take precedence for acceptance purposes.

7. Dimensions

7.1 Bolts and Hex Cap Screws:

7.1.1 Unless otherwise specified, the dimensions of hex cap screws (finished hex bolts), excluding silicon bronze alloy 651, shall be in accordance with the requirements of ASME B18.2.1.

7.1.2 Unless otherwise specified, the dimensions of silicon bronze alloy 651 hex cap screws [finished hex bolt] shall be in accordance with the requirements of ASME B18.2.1; or, the bolts and cap screws shall have a roll thread body diameter

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### TABLE 3 Tensile Stress Areas and Threads per Inch

<table>
<thead>
<tr>
<th>Nominal Size, in.</th>
<th>Coarse Threads-UNC</th>
<th>Fine Threads-UNF</th>
<th>8 Thread Series-8UN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stress Area&lt;sup&gt;a&lt;/sup&gt;, in.&lt;sup&gt;2&lt;/sup&gt;</td>
<td>Stress Area&lt;sup&gt;a&lt;/sup&gt;, in.&lt;sup&gt;2&lt;/sup&gt;</td>
<td>Stress Area&lt;sup&gt;a&lt;/sup&gt;, in.&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Threads/ in.</td>
<td>Stress Area&lt;sup&gt;a&lt;/sup&gt;, in.&lt;sup&gt;2&lt;/sup&gt;</td>
<td>Threads/ in.</td>
</tr>
<tr>
<td>1/8</td>
<td>20</td>
<td>0.0318</td>
<td>28</td>
</tr>
<tr>
<td>5/32</td>
<td>18</td>
<td>0.0524</td>
<td>24</td>
</tr>
<tr>
<td>3/16</td>
<td>16</td>
<td>0.0775</td>
<td>24</td>
</tr>
<tr>
<td>7/32</td>
<td>14</td>
<td>0.1063</td>
<td>20</td>
</tr>
<tr>
<td>1/4</td>
<td>13</td>
<td>0.1419</td>
<td>20</td>
</tr>
<tr>
<td>9/32</td>
<td>12</td>
<td>0.1820</td>
<td>18</td>
</tr>
<tr>
<td>5/16</td>
<td>11</td>
<td>0.2260</td>
<td>18</td>
</tr>
<tr>
<td>3/8</td>
<td>10</td>
<td>0.3340</td>
<td>16</td>
</tr>
<tr>
<td>7/16</td>
<td>9</td>
<td>0.4620</td>
<td>14</td>
</tr>
<tr>
<td>1/2</td>
<td>8</td>
<td>0.6060</td>
<td>12</td>
</tr>
<tr>
<td>11/32</td>
<td>7</td>
<td>0.7630</td>
<td>12</td>
</tr>
<tr>
<td>1/4</td>
<td>7</td>
<td>0.9690</td>
<td>12</td>
</tr>
<tr>
<td>5/32</td>
<td>6</td>
<td>1.1550</td>
<td>12</td>
</tr>
<tr>
<td>3/16</td>
<td>6</td>
<td>1.4050</td>
<td>12</td>
</tr>
</tbody>
</table>

<sup>a</sup>Tensile stress areas are computed using the following formula:

\[ A_s = 0.7854 \left( D - \left( \frac{0.9743}{n} \right) \right)^2 \]

where:

- \( A_s \) = tensile stress area, in.<sup>2</sup>.
- \( D \) = nominal size (basic major diameter), in., and
- \( n \) = number of threads per inch.
8. Workmanship, Finish, and Appearance

8.1 Workmanship—The fasteners shall have a workmanlike finish free of injurious burrs, seams, laps, irregular surfaces, and other imperfections affecting serviceability.

8.2 Finish—Unless otherwise specified, the fasteners shall be furnished without an additive chemical or metallic finish.

9. Sampling

9.1 A lot, for the purposes of selecting test specimens, shall consist of not more than 100,000 pieces offered for inspection at one time having the following common characteristics:

9.1.1 One type of item (that is, bolts, hex cap screws, studs, and so forth).

9.1.2 Same alloy and temper.

9.1.3 One nominal diameter and thread series, and

9.1.4 One nominal length.

10. Number of Tests and Retests

10.1 Number of Tests—The requirements of this specification shall be met in continuous mass production for stock. The manufacturer shall make sample inspections as specified below to ensure that the product conforms to the specified requirements. When tests of individual shipments are required, Supplementary Requirement S2 shall be specified.

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Tests</th>
<th>Acceptance Criteria</th>
<th>Rejection Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 and under</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>51 to 500</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>501 to 35,000</td>
<td>5</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>35,001 to 100,000</td>
<td>8</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

10.2 Retests:

10.2.1 When tested in accordance with the required sampling plan, a lot shall be subject to rejection if any of the test specimens fails to meet the applicable test requirements.

10.2.2 If the failure of a test specimen is due to improper preparation of the specimen or to incorrect testing technique, the specimen shall be discarded and another specimen substituted.

11. Test Preparation

11.1 Chemical Tests—When required, samples for chemical analysis shall be taken in accordance with Practice E 55 by drilling, sawing, milling, turning, clipping, or such other methods capable of producing representative samples.

11.2 Mechanical Tests:

11.2.1 Machined tension specimens, when required, shall be taken in accordance with Test Methods F 606. The largest test specimen that can be machined from the bolt or stud shall be used.

11.2.2 Machined shear test specimens, when required and applicable to aluminum alloys only, shall be taken in accordance with Test Method B 565.

12. Test Methods

12.1 Chemical Analysis—The chemical composition may be determined by any recognized commercial test method. In the event of disagreement, the following test methods shall be used for referee purposes:

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>E 53, E 54, E 62, E 75, E 478</td>
</tr>
<tr>
<td>Aluminum</td>
<td>E 34, E 101, E 227</td>
</tr>
<tr>
<td>Nickel</td>
<td>E 38, E 76, E 354</td>
</tr>
<tr>
<td>Titanium</td>
<td>E 120, E 1409</td>
</tr>
</tbody>
</table>

12.2 Mechanical:

12.2.1 When full-size tests are to be performed, determine the yield strength, wedge tensile strength, and axial tensile strength, as required by Section 6, on each sample in accordance with the appropriate methods of Test Methods F 606.

12.2.2 When machined specimen tests are necessary (see Section 7), determine the yield strength, tensile strength, and elongation on each sample in accordance with Test Methods E 8; and the shear strength (applicable to aluminum alloys only) in accordance with Test Method B 565.

12.2.3 Determine the hardness in accordance with Test Methods E 18 or E 92 at mid radius on the bottom of the threaded end after suitable preparation. Make a minimum of two readings, each of which shall conform to the specified requirements.

13. Significance of Numerical Limits

13.1 For purposes of determining compliance with the specified limits for requirements of the properties listed in this specification, an observed value or calculated value shall be rounded in accordance with Practice E 29.

14. Inspection

14.1 When specified on the inquiry or purchase order, the product shall be subject to inspection by the purchaser at the place of manufacture before shipment. The inspector representing the purchaser shall have controlled entry only to those parts of the manufacturer’s operations that concern the manufacture of the ordered product and only when and where work on the contract of the purchaser is being performed. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the product is being furnished in accordance with this specification.
specification. All inspections and tests shall be conducted so as not to interfere unnecessarily with the operations of the manufacturer.

15. Rejection and Rehearing

15.1 Unless otherwise specified, any rejection based on tests specified herein and made by the purchaser shall be reported to the manufacturer as soon as practical after receipt of the product by the purchaser.

16. Certification and Test Reports

16.1 Certificate of Compliance—When specified in the contract or purchase order, the manufacturer shall furnish certification that the product was manufactured and tested in accordance with this specification and conforms to all specified requirements.

16.2 Test Reports—When shipment lot testing in accordance with Supplementary Requirement S3 is specified in the contract or purchase order, the manufacturer shall furnish a test report showing the results of the mechanical tests for each lot shipped.

17. Product, Packaging and Package Marking

17.1 Individual Fasteners—All products shall be marked with a symbol identifying the manufacturer. In addition, they shall be marked with the alloy/mechanical property marking specified in Table 2. The marking shall be raised or depressed at the option of the manufacturer.

17.2 Packaging:

17.2.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

17.2.2 When special packaging requirements are required by the purchaser, they shall be defined at the time of inquiry and order.

17.3 Package Marking—Each shipping unit shall include or be plainly marked with the following:

17.3.1 ASTM designation,

17.3.2 Alloy number,

17.3.3 Alloy/mechanical property marking,

17.3.4 Size,

17.3.5 Name and brand or trademark of the manufacturer,

17.3.6 Number of pieces,

17.3.7 Country of origin, and

17.3.8 Purchase order number.

18. Keywords

18.1 bolts; cap screws; general use; nonferrous; studs

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser on the inquiry, contract, or order. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Stress Corrosion Requirements

S1.1 Copper Alloys—Copper alloy fasteners shall exhibit no evidence of cracking after immersion for 30 min in an aqueous solution of mercurous nitrate when tested in accordance with Test Method B 154.

S1.1.1 Warning—Mercury is a definite health hazard and equipment for the detection and removal of mercury vapor produced in volatilization is recommended. The use of rubber gloves in testing is advisable.

S1.2 7075-T73 Aluminum Alloy—For aluminum alloy 7075-T73 fasteners, the resistance to stress corrosion cracking shall be established by testing the previously selected tension test specimens to the electrical conductivity-yield strength criteria listed in 12.2 of Specification B 211. When the fasteners are too short to permit tension testing, suitable lengths of the stock used to produce the fasteners shall be heat treated with the fasteners and tested to the electrical conductivity-yield strength criteria. The conductivity shall be determined in accordance with Test Method B 193.

S2. Shipment Lot Testing

S2.1 When Supplementary Requirement S2 is specified on the order (see 3.1.6), the manufacturer shall make sample tests on the individual lots for shipment to ensure that the product conforms to the specified requirements.

S2.2 The manufacturer shall make an analysis of a randomly selected finished fastener from each lot of product to be shipped. Heat or lot control shall be maintained. The analysis of the starting material from which the fasteners have been manufactured may be reported in place of the product analysis.

S2.3 The manufacturer shall perform mechanical property tests in accordance with this specification and Guide F 1470 on the individual lots for shipment.

S2.4 The manufacturer shall furnish a test report for each lot in the shipment showing the actual results of the chemical analysis and mechanical property tests performed in accordance with Supplementary Requirement S2.

S3. Dye Penetrant Inspection

S3.1 When dye penetrant inspection is specified on the purchase order, the fasteners shall be tested in accordance with Practice E 165 or other mutually acceptable procedures, and shall conform to acceptance criteria as mutually agreed upon by the purchaser and manufacturer.

S4. Heat Control (Alloys 400, 405, and 500 Only)

S4.1 When Supplementary Requirement S4 is specified on the inquiry or order, the manufacturer shall control the product by heat analysis and identify the finished product in each shipment by the actual heat number.

S4.2 When Supplementary Requirement S4 is specified on the inquiry or order, Supplementary Requirement S2 shall be considered automatically invoked with the addition that the
heat analysis shall be reported to the purchaser on the test reports.

This standard is issued under the fixed designation F 468M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers the requirements for commercial wrought nonferrous bolts, hex cap screws, and studs in nominal thread diameters M6 to M36 inclusive manufactured from a number of alloys in common use and intended for general service applications.

1.2 Unless otherwise specified, nuts used on these bolts, cap screws, and studs shall conform to the requirements of Specification F 467M. Nuts shall be of the same alloy group as the fastener on which they are used and shall have a specified minimum proof stress equal to or greater than the specified minimum tensile strength stress of the fastener on which they are used.

NOTE 1—This specification is the metric companion of Specification F 468.

2. Referenced Documents

2.1 ASTM Standards:

B 154 Test Method for Mercurous Nitrate Test for Copper and Copper Alloys²
B 193 Test Method for Resistivity of Electrical Conductor Materials³
B 211M Specification for Aluminum and Aluminum-Alloy Bar, Rod, and Wire [Metric]⁴
B 446 Specification for Nickel-Chromium-Molybdenum-Columbium-Alloy (UNS N06625), Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219), and Nickel-Chromium-Molybdenum-Tungsten Alloy (UNS N06650) Rod and Bar⁵
B 565 Test Method for Shear Testing of Aluminum and Aluminum-Alloy Rivets and Cold-Heading Wire and Rods⁶
D 3951 Practice for Commercial Packaging⁶
E 8M Test Methods of Tension Testing of Metallic Materials [Metric]⁷
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials⁷
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications⁸
E 34 Test Methods for Chemical Analysis of Aluminum and Aluminum Base Alloys⁹
E 38 Methods for Chemical Analysis of Nickel-Chromium and Nickel-Chromium-Iron Alloys¹⁰
E 53 Test Methods for Determination of Copper in Unalloyed Copper by Gravimetry⁹
E 54 Test Methods for Chemical Analysis of Special Brasses and Bronzes¹¹
E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition⁹
E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)⁹
E 75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys⁹
E 76 Test Methods for Chemical Analysis of Nickel-Copper Alloys⁹
E 92 Test Method for Vickers Hardness of Metallic Materials⁷
E 101 Test Method for Spectrographic Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique¹²
E 120 Test Methods for Chemical Analysis of Titanium and Titanium Alloys⁹

¹ This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.04 on Nonferrous Fasteners.


² Annual Book of ASTM Standards, Vol 02.01.
³ Annual Book of ASTM Standards, Vol 02.03.
⁴ Annual Book of ASTM Standards, Vol 02.02.
⁵ Annual Book of ASTM Standards, Vol 02.04.
⁷ Annual Book of ASTM Standards, Vol 03.01.
⁹ Annual Book of ASTM Standards, Vol 03.05.
¹⁰ Discontinued 1989; Replaced by E 350.
¹¹ Discontinued; see 2001 Annual Book of ASTM Standards, Vol 03.05.
¹² Discontinued; see 1995 Annual Book of ASTM Standards, Vol 03.05.
3. Ordering Information

3.1 Orders for fasteners under this specification shall include the following information:

3.1.1 Quantity (number of pieces of each item and size);
3.1.2 Name of item. For silicon bronze alloy 651, state if hex cap screw dimensions or roll thread body diameter are required (see 7.1.2);
3.1.3 Dimensions including nominal diameter, thread pitch, and length;
3.1.4 Alloy number (Table 1). For Ti5, state Class A or Class B (Table 2, 6.5, and 6.5.1);
3.1.5 Stress relieving, if required (see 4.2.3);
3.1.6 Shipment lot testing, as required (see Section 10);
3.1.7 Source inspection, if required (see Section 14);
3.1.8 Certificate of compliance or test report, if required (see Section 16);
3.1.9 Additional requirements, if any, to be specified on the purchase order (see 4.2.1, 4.2.4, 7.3.1, 8.2, 11.1, and 12.1);
3.1.10 Supplementary Requirements, if any; and
3.1.11 ASTM specification and year of issue.

Note 2—A typical ordering description is as follows: 10,000 pieces, Hex Cap Screw, M6 × 1 × 80, Alloy 270. Furnish Certificate of Compliance. Supplementary Requirement S1, ASTM F 468M-XX.

4. Materials and Manufacture

4.1 Materials:

4.1.1 The bolts, cap screws, and studs shall be manufactured from material having a chemical composition conforming to the requirements in Table 1 and capable of developing the required mechanical properties for the specified alloy in the finished fastener.

4.1.2 The starting condition of the raw material shall be at the discretion of the fastener manufacturer but shall be such that the finished products conform to all of the specified requirements.

4.2 Manufacture:

4.2.1 Forming—Unless otherwise specified, the fasteners shall be cold formed, hot formed, or machined from suitable material, at the option of the manufacturer.

4.2.2 Condition—Except as provided in 4.2.3, the fasteners shall be furnished in the following conditions:

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper (all alloys)</td>
<td>As formed or stress relieved at manufacturer’s option</td>
</tr>
<tr>
<td>400 and 405</td>
<td>As formed or stress relieved at manufacturer’s option</td>
</tr>
<tr>
<td>500</td>
<td>Solution annealed and aged</td>
</tr>
<tr>
<td>625</td>
<td>Annealed</td>
</tr>
<tr>
<td>Aluminum alloys:</td>
<td></td>
</tr>
<tr>
<td>2024-T4</td>
<td>Solution treated and naturally aged</td>
</tr>
<tr>
<td>6061-T6</td>
<td>Solution treated and artificially aged</td>
</tr>
<tr>
<td>7075-T73</td>
<td>Solution treated and stabilized</td>
</tr>
<tr>
<td>Titanium</td>
<td>As formed</td>
</tr>
</tbody>
</table>

4.2.3 Stress Relieving—When required, stress relieving shall be specified by the purchaser for nickel alloys 400 and 405 and all copper alloys.

4.2.4 Threads—Unless otherwise specified, the threads shall be rolled or cut at the option of the manufacturer.

5. Chemical Composition

5.1 Chemical Composition—The fasteners shall conform to the requirements as to chemical composition prescribed in Table 1 for the specified alloy.

5.2 Manufacturer’s Analysis:

5.2.1 When test reports are required on the inquiry or purchase order (see 3.1.8), the manufacturer shall make individual analyses of randomly selected finished fasteners from the product to be shipped and report the results to the purchaser, except as provided in 5.2.2. Alternatively, if heat and lot identities have been maintained, the analysis of the raw material from which the fasteners have been manufactured may be reported instead of product analysis.

5.2.2 For aluminum fasteners, the manufacturer may furnish instead a certificate of conformance certifying compliance with the chemical composition specified in Table 1.

5.3 Product Analysis:

5.3.1 Product analyses may be made by the purchaser from finished products representing each lot. The chemical composition thus determined shall conform to the requirements in Table 1.

5.3.2 In the event of disagreement, a referee chemical analysis of samples from each lot shall be made in accordance with 11.1 and 12.1.
<table>
<thead>
<tr>
<th>UNS Designation Number</th>
<th>Alloy</th>
<th>General Name</th>
<th>Aluminum, min</th>
<th>Copper, min</th>
<th>Iron, max</th>
<th>Manganese, max</th>
<th>Nickel, max</th>
<th>Phosphorus, max</th>
<th>Silicon, max</th>
<th>Zinc, max</th>
<th>Lead, max</th>
<th>Tin</th>
<th>Arsenic, max</th>
</tr>
</thead>
<tbody>
<tr>
<td>C11000</td>
<td>110</td>
<td>ETP copper</td>
<td>99.9</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>C27000</td>
<td>270</td>
<td>brass</td>
<td>63.0–68.5</td>
<td>0.07</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C46200</td>
<td>462</td>
<td>naval brass</td>
<td>62.0–65.0</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C46400</td>
<td>464</td>
<td>naval brass</td>
<td>59.0–62.0</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>C51000</td>
<td>510</td>
<td>phosphor bronze</td>
<td>balance</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C61300</td>
<td>613</td>
<td>aluminum bronze</td>
<td>6.0–7.5</td>
<td>0.10</td>
<td>0.10</td>
<td>0.15</td>
<td>0.015</td>
<td>0.10</td>
<td></td>
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<tr>
<td>C61400</td>
<td>614</td>
<td>aluminum bronze</td>
<td>6.0–8.0</td>
<td>1.5–3.5</td>
<td>1.0</td>
<td>4.0–5.5</td>
<td>0.25 max</td>
<td>1.5–2.2</td>
<td>0.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C63000</td>
<td>630</td>
<td>aluminum bronze</td>
<td>9.0–11.0</td>
<td>2.0–4.0</td>
<td>1.5</td>
<td>4.0–5.5</td>
<td>0.25 max</td>
<td>1.5–2.2</td>
<td>0.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C64200</td>
<td>642</td>
<td>aluminum silicon bronze</td>
<td>6.3–7.6</td>
<td>0.30</td>
<td>0.10</td>
<td>0.25</td>
<td>1.5–2.2</td>
<td>0.50</td>
<td>0.05</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>C65100</td>
<td>651</td>
<td>silicon bronze</td>
<td>96.0</td>
<td>0.8</td>
<td>0.8</td>
<td>0.15</td>
<td>0.015</td>
<td>0.10</td>
<td></td>
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<tr>
<td>C65500</td>
<td>655</td>
<td>silicon bronze</td>
<td>94.0</td>
<td>0.8</td>
<td>1.5</td>
<td>0.6</td>
<td>0.8–2.0</td>
<td>1.5</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>C66100</td>
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<td>silicon bronze</td>
<td>94.0</td>
<td>0.25</td>
<td>1.5</td>
<td>0.6</td>
<td>0.8–2.0</td>
<td>1.5</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>C67500</td>
<td>675</td>
<td>manganese bronze</td>
<td>0.25 max</td>
<td>0.8–2.0</td>
<td>0.05–0.5</td>
<td>1.5</td>
<td>0.8–2.0</td>
<td>1.5</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>C71000</td>
<td>710</td>
<td>cupro-nickel</td>
<td>74.0</td>
<td>0.60</td>
<td>1.00</td>
<td>19.0–23.0</td>
<td>1.00</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C71500</td>
<td>715</td>
<td>cupro-nickel</td>
<td>65.0</td>
<td>0.40–0.7</td>
<td>1.00</td>
<td>29.0–33.0</td>
<td>1.00</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A Elements shown as balance shall be arithmetically computed by deducting the sum of the other named elements from 100.
B Copper plus specified elements = 99.8 min; copper plus silver = 88.5–91.5.
C Cobalt is to be counted as nickel.
D Minimum content of copper plus all other elements with specified limits shall be 99.5%.
E An alloy containing as high as 2.6% silicon is acceptable provided the sum of all the elements other than copper, silicon, and iron does not exceed 0.30%.

\[\text{Elements shown as balance shall be arithmetically computed by deducting the sum of the other named elements from 100.}\]

\[\text{Copper plus specified elements = 99.8 min; copper plus silver = 88.5–91.5.}\]

\[\text{Cobalt is to be counted as nickel.}\]

\[\text{Minimum content of copper plus all other elements with specified limits shall be 99.5%}\]

\[\text{An alloy containing as high as 2.6% silicon is acceptable provided the sum of all the elements other than copper, silicon, and iron does not exceed 0.30%.}\]
<table>
<thead>
<tr>
<th>UNS Designation Number</th>
<th>Alloy Name</th>
<th>General Name</th>
<th>Aluminum, max</th>
<th>Carbon, max</th>
<th>Chromium, max</th>
<th>Copper, max</th>
<th>Iron, max</th>
<th>Manganese, max</th>
<th>Nickel, max</th>
<th>Phosphorus, max</th>
<th>Silicon, max</th>
<th>Titanium, max</th>
<th>Cobalt, max</th>
<th>Molybdenum, max</th>
<th>Sulfur, max</th>
<th>Vanadium, max</th>
<th>Tungsten, max</th>
</tr>
</thead>
<tbody>
<tr>
<td>N10001</td>
<td>335</td>
<td>Ni-Mo</td>
<td>0.05</td>
<td>1.0 max</td>
<td>4.0–6.0</td>
<td>1.0</td>
<td>balance</td>
<td>balance</td>
<td>0.025</td>
<td>1.00</td>
<td>0.040</td>
<td>0.08</td>
<td>0.5</td>
<td>0.5</td>
<td>0.35–0.85</td>
<td>0.01</td>
<td>0.015</td>
</tr>
<tr>
<td>N10276</td>
<td>276</td>
<td>Ni-Mo-Cr</td>
<td>0.02</td>
<td>14.5–16.5</td>
<td>4.0–7.0</td>
<td>1.00</td>
<td>balance</td>
<td>balance</td>
<td>0.040</td>
<td>0.08</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.35–0.85</td>
<td>0.01</td>
<td>0.015</td>
</tr>
<tr>
<td>N04400</td>
<td>400</td>
<td>Ni-Cu Class A</td>
<td>0.3</td>
<td>balance</td>
<td>2.5</td>
<td>2.0</td>
<td>63.0–70.0</td>
<td>balance</td>
<td>0.015</td>
<td>0.05</td>
<td>0.40 max</td>
<td>1.00</td>
<td>8.0–10.0</td>
<td>0.015</td>
<td>3.2–4.2</td>
<td>15.0–17.0</td>
<td>0.02 max</td>
</tr>
<tr>
<td>N04405</td>
<td>405</td>
<td>Ni-Cu Class B</td>
<td>0.3</td>
<td>balance</td>
<td>2.5</td>
<td>2.0</td>
<td>63.0–70.0</td>
<td>balance</td>
<td>0.015</td>
<td>0.05</td>
<td>0.40 max</td>
<td>1.00</td>
<td>8.0–10.0</td>
<td>0.015</td>
<td>3.2–4.2</td>
<td>15.0–17.0</td>
<td>0.02 max</td>
</tr>
<tr>
<td>N05500</td>
<td>500</td>
<td>Ni-Cu-Al</td>
<td>0.25</td>
<td>balance</td>
<td>2.0</td>
<td>1.5</td>
<td>63.0–70.0</td>
<td>balance</td>
<td>0.015</td>
<td>0.05</td>
<td>0.40 max</td>
<td>1.00</td>
<td>8.0–10.0</td>
<td>0.015</td>
<td>3.2–4.2</td>
<td>15.0–17.0</td>
<td>0.02 max</td>
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<tr>
<td>N06625</td>
<td>625</td>
<td>Ni-Cr-Mo-Cb</td>
<td>0.010</td>
<td>20.0–23.0</td>
<td>5.0</td>
<td>0.50</td>
<td>58.0 min</td>
<td>balance</td>
<td>0.015</td>
<td>0.05</td>
<td>0.40 max</td>
<td>1.00</td>
<td>8.0–10.0</td>
<td>0.015</td>
<td>3.2–4.2</td>
<td>15.0–17.0</td>
<td>0.02 max</td>
</tr>
<tr>
<td>N06686</td>
<td>686</td>
<td>Ni-Cr-Mo-W</td>
<td>0.010</td>
<td>19.0–23.0</td>
<td>5.0</td>
<td>0.75</td>
<td>balance</td>
<td>0.04 max</td>
<td>0.08</td>
<td>0.2–0.25</td>
<td>15.0–17.0</td>
<td>0.02 max</td>
<td>3.0–4.4</td>
<td>15.0–17.0</td>
<td>0.02 max</td>
<td>3.0–4.4</td>
<td></td>
</tr>
</tbody>
</table>

A Elements shown as balance shall be arithmetically computed by deducting the sum of the other named elements from 100.
B Cobalt is to be counted as nickel.
C Alloy 625 material shall be refined using the electroslag remelting process (ESR), or the vacuum arc remelting process (VAR).
<table>
<thead>
<tr>
<th>UNS Designation Number</th>
<th>Alloy</th>
<th>General Name</th>
<th>Aluminum</th>
<th>Chromium</th>
<th>Copper</th>
<th>Iron, max</th>
<th>Manganese, max</th>
<th>Silicon, max</th>
<th>Titanium, max</th>
<th>Zinc, max</th>
<th>Magnesium</th>
<th>Other Elements, max</th>
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<tbody>
<tr>
<td></td>
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</tr>
<tr>
<td>A92024</td>
<td>2024</td>
<td>Aluminum 2024</td>
<td>balance</td>
<td>0.10 max</td>
<td>3.8–4.9</td>
<td>0.50</td>
<td>0.30–0.9</td>
<td>0.50</td>
<td>0.15&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.25</td>
<td>1.2–1.8</td>
<td>0.05 0.15</td>
</tr>
<tr>
<td>A96061</td>
<td>6061</td>
<td>Aluminum 6061</td>
<td>balance</td>
<td>0.04–0.35</td>
<td>0.15–0.40</td>
<td>0.7</td>
<td>0.15</td>
<td>0.40–0.8</td>
<td>0.15</td>
<td>0.25</td>
<td>0.8–1.2</td>
<td>0.05 0.15</td>
</tr>
<tr>
<td>A97075</td>
<td>7075</td>
<td>Aluminum 7075</td>
<td>balance</td>
<td>0.18–0.35</td>
<td>1.2–2.0</td>
<td>0.50</td>
<td>0.30</td>
<td>0.40</td>
<td>0.20&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5.1–6.1</td>
<td>2.1–2.9</td>
<td>0.05 0.15</td>
</tr>
</tbody>
</table>

<sup>a</sup> Analysis shall regularly be made only for the elements specified in this table. If, however, the presence of other elements is suspected or indicated in amounts greater than the specified limits, further analysis shall be made to determine that these elements are not present in excess of the specified limits.

<sup>b</sup> Elements shown as balance shall be arithmetically computed by deducting the sum of the other named elements from 100.

<sup>c</sup> Titanium + zirconium 0.20 %, max.

<sup>d</sup> Lead 0.4–0.7 %; bismuth 0.4–0.7 %.
## TABLE 1 Continued

Titanium and Titanium-Base Alloys

<table>
<thead>
<tr>
<th>UNS Designation Number</th>
<th>Alloy</th>
<th>General Name</th>
<th>Aluminum, Al</th>
<th>Carbon, C</th>
<th>Iron, Fe</th>
<th>Titanium, Ti</th>
<th>Hydrogen, H</th>
<th>Nitrogen, N</th>
<th>Oxygen, O</th>
<th>Palladium, Pd</th>
<th>Vanadium, V</th>
<th>Chromium, Cr</th>
<th>Molybdenum, Mo</th>
<th>Zirconium, Zr</th>
<th>Tin, Sn</th>
<th>Silicon, Si</th>
<th>Ruthenium, Ru</th>
<th>Residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>R50250</td>
<td>1</td>
<td>titanium Gr 1</td>
<td>0.10</td>
<td>0.20</td>
<td>balance</td>
<td>0.0125</td>
<td>0.05</td>
<td>0.18</td>
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<td>balance</td>
<td>0.0125</td>
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<td>0.12</td>
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<td>0.4</td>
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<td></td>
</tr>
</tbody>
</table>

<sup>A</sup> All reported values are maximums, unless a range is specified.

<sup>B</sup> A residual is an element present in a metal or an alloy in small quantities inherent to the manufacturing process but not added intentionally. Residual elements need not be reported unless a report is specifically required by the purchaser.

<sup>C</sup> Identical chemical requirements apply to both Class A and B as defined in Table 2 and 6.5.

<sup>D</sup> Ruthenium and Palladium, or both, may be added to Grade 19 for enhanced corrosion resistance as negotiated between purchaser and vendor. Chemical analysis is not required unless specifically required by the purchaser.


### TABLE 2 Mechanical Property Requirements

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Mechanical Property Marking</th>
<th>Nominal Thread Diameter</th>
<th>Hardness</th>
<th>Full-Size Tests</th>
<th>Machined Specimen Tests</th>
<th>Elongation in 4D, %&lt;sup&gt;4&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tensile Strength, MPa</td>
<td>Yield Strength, min, MPa</td>
<td>Tensile Strength, min, MPa</td>
</tr>
<tr>
<td></td>
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<tr>
<td>Copper</td>
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<tr>
<td>Cu 110</td>
<td>F 468MA</td>
<td>all</td>
<td>65–90 HRF</td>
<td>205–345</td>
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<tr>
<td>Cu 270</td>
<td>F 468MB</td>
<td>all</td>
<td>55–80 HRF</td>
<td>410–620</td>
<td>345</td>
<td>380</td>
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<td>Cu 462</td>
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<td>60–95 HRB</td>
<td>410–620</td>
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<td>380</td>
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<td>Cu 613</td>
<td>F 468MF</td>
<td>M16 to M12</td>
<td>70–95 HRB</td>
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<td>Cu 614</td>
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<td>75–95 HRB</td>
<td>520–760</td>
<td>240</td>
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<td>Cu 651</td>
<td>F 468MK</td>
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<td>all</td>
<td>60–95 HRB</td>
<td>480–830</td>
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<tr>
<td>Ni 405</td>
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<td>all</td>
<td>60 HRB–20 HRC</td>
<td>480–860</td>
<td>205</td>
<td>480</td>
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<tr>
<td>Ni 500</td>
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<td>M6 to M20</td>
<td>24–37 HRC</td>
<td>900–1240</td>
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<td>Ni 625</td>
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<td>85 HRB–35 HRC</td>
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<td>Grade 1</td>
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<td>Grade 2</td>
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<td>23–47 HRC</td>
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<td>25–49 HRC</td>
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<td>AI 2024–T4&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>all</td>
<td>70–85 HRB</td>
<td>380–480</td>
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<td>AI 7075–T7&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>80–90 HRB</td>
<td>420–520</td>
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<td>Titanium&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td>Ti 1</td>
<td>F 468MAT</td>
<td>all</td>
<td>140–160 HV</td>
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<td>F 468MBT</td>
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<td>160–180 HV</td>
<td>345–580</td>
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<td>30–39 HRC</td>
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<td>Ti 23</td>
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<td>25–36 HRC</td>
<td>828–1125</td>
<td>759</td>
<td>828</td>
</tr>
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<td>all</td>
<td>24–38 HRC</td>
<td>725–1035</td>
<td>620</td>
<td>690</td>
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</tbody>
</table>

<sup>a</sup> Where both tension and hardness tests are performed, the tension tests shall take precedence for acceptance purposes. For aluminum and titanium alloys, hardness tests are for information only. See 6.4.

<sup>b</sup> The yield and tensile strength values for full-size products shall be computed by dividing the yield and maximum tensile load by the stress area for the product diameter and thread pitch as given in table on tensile stress areas.

<sup>c</sup> Yield strength is the stress at which an offset of 0.2 % gage length occurs.

<sup>d</sup> Elongation is determined using a gage length of 4 diameters of test specimen in accordance with Test Methods E 8.

<sup>e</sup> “HF” denotes a hot-formed product.

<sup>f</sup> Aluminum alloy temper designations are in accordance with ANSI H35.1.

<sup>g</sup> Full-size test mechanical properties apply to fasteners with a maximum diameter of 76 mm. Mechanical properties of larger sections shall be negotiated between the material manufacturer and the fastener producer.

<sup>h</sup> Ti 5 Class A requires wedge tensile testing in accordance with 6.5. Ti 5 Class B requires wedge tensile testing in accordance with 6.5.1.
6. Mechanical Properties

6.1 The fasteners shall be tested in accordance with the mechanical testing requirements for the applicable type, length of product, and minimum tensile strength and shall meet the mechanical properties in Table 2 and Table 3 for the specified alloy.

6.2 Fasteners having a length equal to or longer than the “minimum length of product requiring tension testing” as specified in Test Methods F 606M and a breaking load of 530 kN or less shall be tested full size and shall meet the full-size tensile (minimum and maximum) and yield strength properties in Table 2 for the specified alloy.

6.3 Fasteners having a length equal to or longer than the “minimum length of product requiring tension testing” as specified in Test Methods F 606M and a breaking load exceeding 530 kN shall preferably be tested full size and shall meet the full-size tensile (minimum and maximum) and yield strength properties in Table 2. When equipment of sufficient capacity for such tests is not available, or if excessive length of the bolts or stud makes full-size testing impractical, standard round specimens shall be used that shall meet the “machined specimen tests” tensile properties in Table 2. In the event of a discrepancy between full-size and machined specimen tension tests, full-size tests shall be used as the referee method to determine acceptance.

6.4 For all alloys except aluminum and titanium, fasteners that are too short (lengths less than that specified in Test Methods F 606M as the “minimum length of product requiring tension testing”), that have insufficient threads for tension testing (see 11.2), or that have drilled or undersized heads weaker than the thread section, are not subject to tension tests but shall conform to the minimum and maximum hardness in Table 2. Hardness tests are not applicable to aluminum and titanium alloys. When required for aluminum alloys, a shear test shall be performed in accordance with 11.2.2 and 12.2.2.

6.5 Full-size bolts and cap screws subject to tension tests shall be tested using a wedge under the head. Wedge angles shall be as follows, except for Ti 5 Class B, which shall use wedge angles as defined in 6.5.1. The wedge shall be 10° for bolts and cap screws of nominal thread M20 and less, and 6° for bolts and cap screws over M20. For bolts and cap screws threaded essentially to the head, the wedge angle shall be 6° for diameters M20 and less, and 4° for sizes over M20.

6.5.1 Ti 5 Class B wedge angles shall be 6° for bolts and cap screws of M20 nominal diameter and less, and 4° for bolts and cap screws over M20 diameter. For bolts and cap screws threaded essentially to the head, the wedge angle shall be 4° for bolts and cap screws of M20 nominal diameter and less, and 2° for bolts and cap screws over M20 diameter.

6.6 Where both tension and hardness tests are performed, the tension test results shall take precedence for acceptance purposes.

7. Dimensions

7.1 Bolts and Hex Cap Screws:

7.1.1 Unless otherwise specified, the dimensions of hex cap screws (finished hex bolts), excluding silicon bronze alloy 651, shall be in accordance with the requirements of ASME B18.2.3.1M.

7.1.2 Unless otherwise specified, the dimensions of silicon bronze alloy 651 hex cap screws [finished hex bolt] shall be in accordance with the requirements of ASME B18.2.3.1M; or, the bolts and cap screws shall have a roll thread body diameter (that is, body with minimum diameter equal to the pitch diameter), with all other dimensions in accordance with ASME B18.2.3.1M, as specified by the purchaser.

7.1.3 When specified, the dimensions of bolts shall be in accordance with the requirements of ASME B18.2.3.5M, or such other dimensions as specified.

7.2 Studs—The dimensions of studs shall be as specified by the purchaser. Studs shall be of the continuous thread; double-end interference (also known as stud bolt and bolt stud); or double-end interference (also known as tap-end stud) types as specified by the purchaser.

7.3 Threads:

7.3.1 Unless otherwise specified, the bolts, cap screws, and studs shall have threads in accordance with ASME B1.13M, tolerance grade 6g.

7.3.2 For silicon bronze alloy 651, the thread length for bolts ordered with roll thread body diameter shall conform to the following:

<table>
<thead>
<tr>
<th>Bolt Length, mm</th>
<th>Thread Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 and less</td>
<td>within 2 threads of the head</td>
</tr>
<tr>
<td>Over 50 to 150</td>
<td>50 mm min + 2 threads</td>
</tr>
<tr>
<td>Over 150</td>
<td>75 mm min + 2 threads</td>
</tr>
</tbody>
</table>

8. Workmanship, Finish, and Appearance

8.1 Workmanship—The fasteners shall have a workmanlike finish free of injurious burrs, seams, laps, irregular surfaces, and other imperfections affecting serviceability.

8.2 Finish—Unless otherwise specified, the fasteners shall be furnished without an additive chemical or metallic finish.

9. Sampling

9.1 A lot, for the purposes of selecting test specimens, shall consist of not more than 100,000 pieces offered for inspection at one time having the following common characteristics:

9.1.1 One type of item (that is, bolts, hex cap screws, studs, etc.),

### TABLE 3 Tensile Stress Areas

<table>
<thead>
<tr>
<th>Nominal Product Diameter and Thread Pitch</th>
<th>Stress Area, mm²</th>
<th>Nominal Product Diameter and Thread Pitch</th>
<th>Stress Area, mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>M6 × 1</td>
<td>20.1</td>
<td>M16 × 2</td>
<td>157</td>
</tr>
<tr>
<td>M8 × 1.25</td>
<td>36.6</td>
<td>M20 × 2.5</td>
<td>245</td>
</tr>
<tr>
<td>M10 × 1.5</td>
<td>58.0</td>
<td>M24 × 3</td>
<td>353</td>
</tr>
<tr>
<td>M12 × 1.75</td>
<td>84.3</td>
<td>M30 × 3.5</td>
<td>561</td>
</tr>
<tr>
<td>M14 × 2</td>
<td>115</td>
<td>M36 × 4</td>
<td>817</td>
</tr>
</tbody>
</table>

A tensile stress areas are computed using the following formula:

\[ A_s = 0.7954 \left( \frac{D^2}{D - 0.9382 P} \right) \]

where:
- \( A_s \) = stress area, mm²,
- \( D \) = nominal thread diameter, mm, and
- \( P \) = thread pitch, mm.
9.1.2 Same alloy and temper.
9.1.3 One nominal diameter and thread pitch, and
9.1.4 One nominal length.

10. Number of Tests and Retests

10.1 Number of Tests—The requirements of this specification shall be met in continuous mass production for stock. The manufacturer shall make sample inspections as specified below to ensure that the product conforms to the specified requirements. When tests of individual shipments are required, Supplementary Requirement S2 shall be specified.

10.2 Retests:

10.2.1 When tested in accordance with the required sampling plan, a lot shall be subject to rejection if any of the test specimens fails to meet the applicable test requirements.

10.2.2 If the failure of a test specimen is due to improper preparation of the specimen or to incorrect testing technique, the specimen shall be discarded and another specimen substituted.

11. Specimen Preparations

11.1 Chemical Tests—When required, samples for chemical analysis shall be taken in accordance with Practice E 55 by drilling, sawing, milling, turning, clipping, or such other methods capable of producing representative samples.

11.2 Mechanical Tests:

11.2.1 Machined tension specimens, when required, shall be taken in accordance with Test Methods F 606M. The largest test specimen that can be machined from the bolt or stud shall be used.

11.2.2 Machined shear test specimens, when required and applicable to aluminum alloys only, shall be taken in accordance with Test Method B 565.

12. Test Methods

12.1 Chemical Analysis—The chemical composition may be determined by any recognized commercial test method. In the event of disagreement, the following test methods shall be used for referee purposes:

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>E 53, E 54, E 62, E 75, E 478</td>
</tr>
<tr>
<td>Aluminum</td>
<td>E 34, E 101, E 227</td>
</tr>
<tr>
<td>Nickel</td>
<td>E 38, E 76, E 354</td>
</tr>
<tr>
<td>Titanium</td>
<td>E 120, E 1409</td>
</tr>
</tbody>
</table>

12.2 Mechanical:

12.2.1 When full-size tests are to be performed, determine the yield strength, tensile strength, and chord tensile strength, as required by Section 6, on each sample in accordance with the appropriate methods of Test Methods F 606M.

12.2.2 When machined specimen tests are necessary (see Section 6), determine the yield strength, tensile strength, and elongation on each sample in accordance with Test Methods E 8M; and the shear strength (applicable to aluminum alloys only) in accordance with Test Method B 565.

12.2.3 Determine the hardness in accordance with Test Methods E 18 or E 92 at mid-radius on the bottom of the threaded end after suitable preparation. Make a minimum of two readings, each of which shall conform to the specified requirements.

13. Significance of Numerical Limits

13.1 For purposes of determining compliance with the specified limits for requirements of the properties listed in this specification, an observed value or calculated value shall be rounded in accordance with Practice E 29.

14. Inspection

14.1 When specified on the inquiry or purchase order, the product shall be subject to inspection by the purchaser at the place of manufacture prior to shipment. The inspector representing the purchaser shall have controlled entry only to those parts of the manufacturer’s operations that concern the manufacture of the ordered product and only when and where work on the contract of the purchaser is being performed. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the product is being furnished in accordance with this specification. All inspections and tests shall be conducted so as not to interfere unnecessarily with the operations of the manufacturer.

15. Rejection and Rehearing

15.1 Unless otherwise specified, any rejection based on tests specified herein and made by the purchaser shall be reported to the manufacturer as soon as practical after receipt of the product by the purchaser.

16. Certification and Test Reports

16.1 Certificate of Compliance—When specified in the contract or purchase order, the manufacturer shall furnish certification that the product was manufactured and tested in accordance with this specification and conforms to all specified requirements.

16.2 Test Reports—When shipment lot testing in accordance with Supplementary Requirement S3 is specified in the contract or purchase order, the manufacturer shall furnish a test report showing the results of the mechanical tests for each lot shipped.

17. Product, Packaging and Package Marking

17.1 Individual Fasteners—All products shall be marked with a symbol identifying the manufacturer. In addition, they shall be marked with the alloy/mechanical property marking specified in Table 2. The markings shall be raised or depressed at the option of the manufacturer.

17.2 Packaging:

17.2.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

17.2.2 When special packaging requirements are required by the purchaser, they shall be defined as the time of inquiry and order.
17.3 Package Marking—Each shipping unit shall include or be plainly marked with the following:
17.3.1 ASTM specification,
17.3.2 Alloy number,
17.3.3 Alloy/mechanical property marking,
17.3.4 Size,
17.3.5 Name and brand or trademark of the manufacturer,
17.3.6 Number of pieces,
17.3.7 Country of origin, and
17.3.8 Purchase order number.

18. Keywords
18.1 bolts; cap screws; general use; nonferrous; studs

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser on the inquiry, contract, or order. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Stress Corrosion Requirements

S1.1 Copper Alloys—Copper alloy fasteners shall exhibit no evidence of cracking after immersion for 30 min in an aqueous solution of mercurous nitrate when tested in accordance with Test Method B 154.

S1.1.1 Warning—Mercury is a definite health hazard, and equipment for the detection and removal of mercury vapor produced in volatilization is recommended. The use of rubber gloves in testing is advisable.

S1.2 7075-T73 Aluminum Alloy—For aluminum alloy 7075-T73 fasteners, the resistance to stress corrosion cracking shall be established by testing the previously selected tension test specimens to the electrical conductivity-yield strength criteria listed in 12.2 of Specification B 211M. When the fasteners are too short to permit tension testing, suitable lengths of the stock used to produce the fasteners shall be heat treated with the fasteners and tested to the electrical conductivity-yield strength criteria. The conductivity shall be determined in accordance with Test Method B 193.

S2. Shipment Lot Testing

S2.1 When Supplementary Requirement S2 is specified on the order (see 3.1.6), the manufacturer shall make sample tests on the individual lots for shipment to ensure that the product conforms to the specified requirements.

S2.2 The manufacturer shall make an analysis of a randomly selected finished fastener from each lot of product to be shipped. Heat or lot control shall be maintained. The analysis of the starting material from which the fasteners have been manufactured shall be reported in place of the product analysis.

S2.3 The manufacturer shall perform mechanical property tests in accordance with this specification and Guide F 1470 on the individual lots for shipment.

S2.4 The manufacturer shall furnish a test report for each lot in the shipment showing the actual results of the chemical analysis and mechanical property tests performed in accordance with Supplementary Requirement S2.

S3. Dye Penetrant Inspection

S3.1 When dye penetrant inspection is specified on the purchase order, the fasteners shall be tested in accordance with Practice E 165 or other mutually acceptable procedures and shall conform to acceptance criteria as mutually agreed upon by the purchaser and manufacturer.

S4. Heat Control (Alloys 400, 405, and 500 Only)

S4.1 When Supplementary Requirement S4 is specified on the inquiry or order, the manufacturer shall control the product by heat analysis and identify the finished product in each shipment by the actual heat number.

S4.2 When Supplementary Requirement S4 is specified on the inquiry and order, Supplementary Requirement S2 shall be automatically invoked with the addition that the heat analysis shall be reported to the purchaser on the test reports.
Standard Terminology of Nails for Use with Wood and Wood-Base Materials

This standard is issued under the fixed designation F 547; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

The terms included in these definitions are listed in alphabetical order under six headings to facilitate quick reference. They are intended to apply to metal nails. Some of these terms are also applicable to plastic nails. Omitted are terms relating to tacks, pins, drift pins, dowels, studs, spikes, staples, and other fasteners, such as nail plates. Also omitted are terms relating to the testing and the performance of nails, that is, their drivability, withdrawal resistance, lateral load transmission, creep, protrusion resistance, and splitting; and methods of use, such as face, toe, side, and end-nailing, spacing, loading conditions, etc. These subject matters will be covered in a separate definition of terms relating to mechanical fasteners.

Common acceptance and usage are the basis for most of the definitions listed. In some instances, this common usage results in more than one definition for a given term. In other cases, registered trademarks have become generic in nature; hence, they are included among the terms listed.

Any such listing cannot be complete. As additional terms are referred to the Society’s attention, they will be included.

An asterisk (*) behind the name of a nail indicates that this particular nail type is described in ASTM Specification F 1667 Driven Fasteners: Nails, Spikes, and Staples.

Whereas dimensions are normally not part of a definition, they are included in this standard because they are essential in fully describing the fastener under consideration.

The definitions are listed under the following headings:

NAIL
Nail — straight, slender fastener, usually pointed and headed; 6 in. or less in length; designed to be driven; to hold two or more pieces together or to act as support. (See screw nail; drive screw.)

Discussion — In contrast to screw—fastener, usually pointed and headed; designed to be turned with a screwdriver or other device; having in its simplest form one or two continuous spiral threads (such as a wood screw thread) or a helical thread (such as a machine screw thread) or combinations thereof (such as a sheet-metal screw thread).

NAIL TYPES

aluminum common nail* — plain-shank, aluminum-alloy, 1 by 0.072 to 6 by 0.262-in. nails with flat 5/2 to 17/2-in. head and medium diamond point.

apple-box nail — coated, regular-stock-steel, 1 1/2 and 1 3/4 by 0.080-in. nails with flat 15/64-in. head and medium diamond point.

asbestosboard nail — galvanized, hardened-steel, helically threaded, 1 1/4 and 1 1/2 by 0.083-in. screwnails with flat, slightly countersunk, 3/16-in. head and blunt diamond point.

asbestos-shingle nail — See shingle nail.

asphalt-shingle nail — See roofing nail.

auto nail — nail of 1/4 to 5 1/4-in. length, sheared off bright, smooth, knurled, or helically fluted, regular-stock-steel or stiff-stock, 0.032-in. (21-gage) to 0.162-in. (8-gage) wire and driven subsequently by the same machine at a rapid rate. This nail has a sheared-bevel or sheared-square point.

barrel nail* — bright or coated, regular-stock-steel, 3/4 by 0.067 to 1 1/2 by 0.092-in. nails with flat 0.148 to 0.219-in. head and medium diamond point.

basket nail — bright, regular-stock-steel, 3/4 and 3/8 by 0.048-in. nails with large flat head and medium needle point.
beer-case hinge, lock and latch nail—bright, regular-stock-steel, 1\% by 0.080 to 1\% by 0.106-in. nails with \(\frac{3}{16}\) to \(\frac{3}{8}\)-in. oval head and duckbill or clinch point.

beer-case strap nail—bright, regular-stock-steel, 1\% by 0.080 to 1\% by 0.092-in. nails with oval \(\frac{3}{16}\) to \(\frac{3}{8}\)-in. head and duckbill or clinch point.

beer-case cleat nail—bright, regular-stock-steel, 1\% by 0.080 to 1\% by 0.092-in. nails with oval \(\frac{3}{16}\) to \(\frac{3}{8}\)-in. head and medium diamond point.

brad*—slender, usually small, regular-stock-steel nails of same thickness throughout, but tapering in width; with slight projection on one side serving as head. Also, tapering, square-bodied, finishing nail with countersunk head. Different types of head designed for fastening \(\frac{1}{2}\), \(\frac{3}{4}\), \(\frac{3}{2}\), and \(\frac{3}{4}\)-in. nails with flat and medium diamond point.

cigar-box nail—bright, smooth, or barbed, regular-stock-steel, \(\frac{1}{2}\), \(\frac{3}{8}\), \(\frac{3}{4}\), and by 0.044-in. nails with flat slightly countersunk 0.099-in. head and medium diamond point.

collart—L-shaped nail.

clew nail—bright, regular-stock-steel, 1\% by 0.080 to 1\% by 0.106-in. nails with oval \(\frac{3}{16}\) to \(\frac{3}{8}\)-in. head and duckbill or clinch point. (See clinch nail.)

cliner nail—any nail designed for clinching after driving. Bright, regular-stock-steel, 1 by 0.080 to 4 by 0.177-in. nails with oval \(\frac{3}{16}\) to \(\frac{3}{8}\)-in. head and duckbill or clinch point. (See cleat nail.)

closet nail—bright, regular-stock-steel, \(\frac{3}{4}\) by 0.072 to 1\% by 0.092-in. nails with large flat 0.225 to 0.262-in. head and long side point or duckbill point.

collar nail—See collar head, gudgeon, projection head.

common brad—See brad.

common cut nail*—normally, wedge-shaped, \(\frac{1}{2}\) to 6-in. nails of various types sheared from stiff-stock-sheet steel, with sheared-square point end narrower than upset head end.

common nail*, common wire nail—bright, plain-shank, regular-stock-steel, \(\frac{1}{2}\) by 0.035 to 6 by 0.262-in. nails with flat \(\frac{3}{16}\) to \(\frac{3}{8}\)-in. head and medium diamond point. Diameter is larger than that for sinkers, coolers, corksers, and box nails of same length.

concrete nail*, concrete stub nail—hardened-steel, \(\frac{1}{2}\) by 0.135 to 3 \(\frac{1}{2}\) by 0.207-in. nails with flat countersunk \(\frac{3}{8}\) to \(\frac{3}{8}\)-in. head and medium diamond point.

conduit nail—bright or copper-plated, regular-stock-steel or hardened-steel, \(\frac{1}{2}\) to \(\frac{3}{4}\) by 0.161-in. nails with annularly threaded shank; bent, curved hook head, and medium needle point. Different types of head designed for fastening \(\frac{1}{2}\), \(\frac{3}{4}\), \(\frac{3}{4}\), or 1-in. conduit, tubing, pipe, cable, etc.

cooler nail—usually coated, slender, regular-stock-steel, 1 by 0.062 to 2\% by 0.120-in. nails with flat \(\frac{3}{16}\) to \(\frac{3}{8}\)-in. head and medium diamond point, with head diameter same as or smaller than that of common wire nail of same length.

copper common nail*—bright, solid-copper, \(\frac{1}{4}\) by 0.065 to 6 by 0.284-in. nails with flat head and medium diamond point.

corker nail*—usually coated, slender, regular-stock-steel, 1 by 0.062 to 5\% by 0.244-in. nails with \(\frac{3}{8}\) to \(\frac{3}{8}\)-in. sinker head and medium diamond point.

cork insulation nail—galvanized, regular-stock-steel, 3 to 9 by 0.148-in. nails with flat \(\frac{1}{2}\)-in. head and medium diamond point.

corrugated roofing/siding nail—See roofing nail.

dating nail—galvanized, regular-stock-steel, copper or brass, \(\frac{1}{2}\) by \(\frac{1}{4}\) to 2\% by \(\frac{3}{16}\)-in. nails with \(\frac{3}{8}\) to \(\frac{3}{8}\)-in. flat numeral head and medium diamond point.

diaphragm nail—stout, bright or galvanized, regular-stock-steel or hardened-steel, helically threaded, \(\frac{1}{2}\) by 0.135 to 2\% by 0.148-in. nails with flat slightly countersunk \(\frac{3}{16}\)-in. head and medium diamond point.

double-headed*, duplex-head, dual-head, nail—bright or coated, regular-stock-steel, \(\frac{1}{2}\) by 0.113 to 4 by 0.207-in. nails with double \(\frac{3}{16}\) to \(\frac{3}{16}\)-in. head, medium diamond point, and \(\frac{3}{4}\) to \(\frac{1}{16}\)-in. distance between head to be struck by hammer and bearing head. Length of nails measured from bearing surface of head.

brad—normal, wedge-shaped, 1\% to 6-in. nails.

brick siding nail—galvanized, colored (baked-lacquer finished), plain-shank barbed or annularly threaded, regular-stock-steel, \(\frac{3}{4}\) by 0.092 to 2\% by 0.099-in. nails with flat checkered \(\frac{3}{16}\) or \(\frac{3}{16}\)-in. head and medium diamond point.

cap nail—bright, galvanized or electroplated, plain-shank or threaded, regular-stock-steel, \(\frac{3}{4}\) by 0.105 to 6 by 0.135-in. nails with integral nominal 1-in. cap head and medium diamond point.

car nail—light-duty or heavy-duty, bright or coated, barbed or helically threaded, regular-stock-steel, \(\frac{1}{2}\) by 0.105-in. (light) or 0.135-in. (heavy) to 6 by 0.225-in. (light) or 0.244-in. (heavy) nails and screwnails with flat or oval countersunk head and medium diamond point. Also, light-duty or heavy-duty, coated, barbed or helically threaded, regular-stock-steel, 1\% by 0.092 or 0.106 to 6 by 0.207 or 0.225-in. nails with oval countersunk \(\frac{3}{16}\) to \(\frac{3}{16}\)-in. head and medium diamond point.

casing nail*—bright or galvanized, slender, regular-stock-steel, 1 by 0.067 to 3\% by 0.135-in. nails with flat or cupped 0.099 to 0.177-in. casing head and medium diamond point for countersinking where concealment is important.

box nail*—bright, coated or galvanized, regular-stock-steel, 1 by 0.058 to 5 by 0.162-in. nails, made of lighter-gage wire than common nails and sinkers, with flat \(\frac{1}{16}\) to \(\frac{3}{16}\)-in. head and medium diamond point.
drive nail, drive screw—terms applied to helically threaded nails, twisted nails, and annularly threaded shoe nail. (See nail, thread.)
drywall nail—See gypsum-wallboard nail.
dual-head nail—See double-headed nail.
duplex-head nail—See double-headed nail.
egg-case nail—coated, regular-stock-steel, 1 ¼ by 0.072-in. nail with flat ½-in. head and sharp medium diamond point.
escutcheon pin—small, regular-stock-steel or nonferrous, ¼ by 0.035 to 2 by 0.092-in. nails with oval head and medium diamond point.
face nail—See siding nail.
fence nail—stout, bright, regular-stock-steel, 1½ by 0.135 to 4 by 0.225-in. nails with large flat ½ to 1½-in. head and medium diamond point.
fetter ring nail—term applied to annularly threaded nailed. (See thread.)
fiberboard nail—bright or electroplated, regular-stock-steel or hardened-steel 1 by 0.054 to 2 by 0.062-in. nails with flat ½ or ¾-in. head and medium needle point.
field-box nail—coated, barbed, regular-stock-steel, 2 by 0.099 to 2½ by 0.106-in. nails with ¼-in. oval head and medium diamond point.
file-grip nail, file-thread nail—terms applied to helically threaded nails provided with file threads. (See thread.)
fine nail*—slender, bright, regular-stock-steel, ½ by 0.035 to 1 ½ by 0.072-in. nails with flat ¼ to ⅛-in. head and medium diamond point. Also, slender, electroplated, hardened-steel, 1¼ by 0.054 to 2½ by 0.083-in. nails with brad head and short diamond point.
finishing nail*—slender, bright, regular-stock-steel, 1 by 0.058 to 4 by 0.135-in. nails with flat or cupped 0.086 to 0.177-in. brad head and medium diamond point for countersinking where concealment of head is important. (See also, fine nail, moulding and trim nails, wallboard nails.)
fire-door nail—bright, regular-stock-steel, barbed, 1½ by 0.092-in. nail (3d shingle nail) with flat ⅛-in. head and medium diamond point and 2 by 0.099-in. nail (6d box nail) with flat ⅜-in. head and medium diamond point.
flattened-shank nail—round wire nail with portion of shank flattened for a certain distance between parent and head to facilitate driving of nail between steel members and wrapping of flattened portion of shank around steel rod during driving.
flooring brad—bright, regular-stock-steel, 2 by 0.120 to 4 by 0.192-in. nails with deep (32°) countersunk flat or cupped 0.162 to 0.244-in. head and medium diamond point. Also, slender, bright, regular-stock-steel, ⅝ by 0.076 to 2½ by 0.113-in. nails with deep (32°) countersunk flat or cupped or brad 0.128 to 0.155-in. head and blunt diamond point.
machine flooring brad—bright, regular-stock-steel, 1 by 0.072-in. nail with special 0.113-in. brad head with cylindrical rim and medium diamond point.
flooring nail*—bright, stiff-stock or hardened-steel, helically threaded, 1 by 0.072 to 3½ by 0.148-in. nails with flat or checkered %¼ to %½-in. countersunk or casing head and blunt diamond point.
foundry nail, smooth foundry nail—bright, regular-stock-steel, ¾ by 0.120 to 9 by 0.162-in. nails with large thin flat ⅛ to ½-in. head and medium diamond point.
framing nail—See common nail, threaded common nail, threaded nail.
fruit-box nail—coated, regular-stock-steel, 1½ by 0.072-in. nail with flat ⅜-in. head and medium diamond point.
furniture nail—plated, regular-stock-steel or brass, % by ¾-in. nails with extra large, decorative head and long diamond or needle point.
furniture-carton nail—bright, regular-stock-steel, ¼ to 2-in. nails with circular 1-in. cap head and medium diamond point. (See cap nail.)
furring nail—See self-furring nail.
general-purpose nail—See common nail.
glulam rivet nail*—plain or galvanized, flat, hardened-steel, 2½ by ⅛-in. nail with sheared V-shaped point and flat upset wedge-shaped head; designed to be driven through underside truncated apertures in regular-stock-steel connector plates from which nails cantilever into wood.
gudgeon—bright, regular-stock-steel nails with annular flange or collar located along shank. (See tile nail, acoustical.)
gypsum-deck nail—helically threaded cap nails with special type of thread with extra large lead angle.
gypsum-lath nail—bright or blued, regular-stock-steel, 1 by 0.092 to 1⅜ by 0.166 and 1½ by 0.092-in. nails with large flat ⅛ to ⅜-in. head and long diamond point. Also, regular-stock-steel, 1 by 0.120 to 1½ by 0.148-in. nails with flat ⅛-in. head and medium diamond point. Also, aluminum-alloy, 1½ by 0.099 to 1½ by 0.105-in. nails with flat ⅛ or ¼-in. head and medium diamond point.
gypsum-sheathing nail—galvanized, barbed, regular-stock-steel, 1¼ by 0.120-in. nail with flat ⅛-in. head and medium diamond point.
gypsum-wallboard nail*, gypsum-board nail*, drywall nail*—bright or blued, regular-stock-steel, annularly threaded, 1½ by 0.098 to 2 by 0.105-in. nails with flat, nub, or crossed slightly countersunk ¼ to ½-in. head and long diamond point. Also, slender, colored (baked-lacquer finished), regular-stock-steel, smooth or annularly threaded, 1½ by 0.062 to 2 by 0.083-in. nails with slightly countersunk 0.181-in. head and medium diamond or long needle point.
hardboard nail—slender, usually colored (baked-lacquer finished), stiff-stock or usually hardened-steel, usually annularly threaded, 1 to 1½ by 0.058-in. nails with small flat head and long needle point for fastening plain or prefinished ½ and ¾-in. hardboard for interior applications. Also, slender bright or colored (baked-lacquer finished), galvanized, stiff-stock, or usually hardened-steel, usually helically threaded, 2 to 3 by 0.105 and 0.120-in. nails with countersunk ⅛ or ¼-in. head and pilot needle point for fastening hardboard for exterior applications.
hardened nail—heat-treated medium-low or medium-high carbon-steel nail.
heavy nail, heavy-gage nail—See stout nail.
high-density fiberboard nail—See shake nail, shingle nail, wood shingle and asbestos shingle nail.
hinge nail—light or heavy, bright, regular-stock-steel, 1/4 by 3/4 to 4 by 3/4-in. nails with flat or oval countersunk (95°) or oval 1/4 to 1/2-in. head and long diamond or chisel point.

hob nail—stout, regular-stock-steel, 3/8 to 5/8-in. nails with large decorative (high square, fancy, round bevel, checkered, grooved, etc.) head and sheared-bevel point.

hook-head metal-lath nail—See metal-lath nail.

hook fastener nail—bright, blued or galvanized, regular-stock-steel, 3/8 to 1 by 0.126-in. nails with thin flat 3/8 to 1 1/2-in. long, 0.207 to 3/8-in. wide hook head and medium diamond point.

insulating siding nail—See brick-siding nail.

insulation building-board nail, tileboard nail—galvanized, electro-galvanized or cadmium or nickel-plated, regular-stock-steel, 1 1/4 and 1 1/2 by 0.054-in. nails with flat 3/8-in. head and medium needle point. Also, plain or colored (baked-lacquer finished) hardened-steel, smooth or annularly threaded, 1 1/4 by 0.054 to 1 1/4 by 0.062-in. nails with slightly countersunk 0.109-in. head and medium diamond or long needle point.

insulation lath nail—blued, regular-stock-steel, 1 1/2 and 1 1/4 by 0.092-in. nails with flat 3/8-in. head and long diamond point. (See gypsum-lath nail.)

insulation sheathing nail—galvanized, barbed, regular-stock-steel, 1 1/2 and 2 by 0.115 or 0.120-in. nails with flat 3/8 or 1/2-in. head and medium diamond point.

lath nail*—See metal-lath nail, wood-lath nail.

lead head nail—See roofing nail.

lino nail—bright, regular-stock-steel, 3/8 by 0.062-in. nail with oval head and medium diamond point.

marking nail—See dating nail, marking head, numeral head.

masonry nail*—plain, electro-zinc-plated or galvanized, hardened-steel, knurled (longitudinally or nearly longitudinally threaded or fluted), 1/2 to 4 by 0.148 or up to 0.250-in. nails with flat or checkered 3/16 to 3/16-in. head and medium diamond point.

metal lath nail, hook head metal lath nail*—bright, blued or galvanized, regular-stock-steel, 1 1/8 by 0.106-in. nail with thin flat 3/16 or 1/2-in. hook head and medium diamond point. (See self-furring nail.)

moulding and trim nail—bright zinc-plated, slim, hardened-steel, 1/4 by 0.054 to 2 1/2 by 0.083-in. nails with blunt point and button head. (See finishing nail, fine nail, hardboard nail, insulation building-board nail, tileboard nail, wallboard nail.)

orange-box nail—coated, regular-stock-steel, 1 1/4 by 0.072-in. nail with flat 3/8-in. head and medium diamond point.

pallet nail*—bright, stiff-stock or hardened-steel, helically threaded (with medium lead angle) or annularly threaded, 1 1/2 by 0.105 to 4 by 0.177-in. nails with smooth or checkered flat 9/32 to 7/16-in. head and medium or blunt diamond or blunt chisel point.

parquet flooring nail—hardened-steel, annularly threaded, 1 1/4 by 0.062 to 1 1/4 by 0.072-in. nails with deep countersunk 0.080 to 0.113-in. casing head and diamond or needle point.

peerless cut nail—name for small, regular-stock-steel, cut nails with broad flat circular head and sheared long-tapered square point to facilitate clinching.

pin—small headless nail.

plaster base nail, plasterboard nail, plaster board nail—See gypsum lath nail, wood lath nail.

pole barn nail—bright or galvanized, stiff-stock or hardened-steel, helically threaded, 2 1/2 to 9-in. nails with flat head and medium diamond point. (See threaded nail.)

purlin nail, “straw”—galvanized, regular-stock-steel, aluminum-alloy or copper, 4 to 16 by 5/8-in., 0.135 or 0.148-in. nails of desired length with flat 15/32-in. curved or 11/32-in. head, 15/36-in. cast lead head or plastic washer and sheared-square or diamond point; for securing corrugated roofing to I-beams.

ratchet nail—bright, regular-stock-steel, 3/4 to 2 by 0.120-in. nails with single-crest annular ratchet thread, flat 3/8-in. head and medium diamond point.

ring nail, ring-barbed nail, ring grooved nail, ring grip nail, ring shank nail—terms applied to annularly threaded nail. (See thread, annular.)

roll grooved nail—bright or plated, helically grooved, round wire, stiff-stock, 1 by 0.086 to 4 by 0.164-in. drive-screw nails with no clearance between flutes and head, with flat or slightly countersunk head and medium or long diamond point, with crest diameter being referred to as diameter.

roof deck nail—galvanized, regular-stock-steel and bright, hardened-steel, plain or annularly threaded, 3 by 0.135 to 4 1/2 by 0.177-in. nails with flat or slightly countersunk 9/32 to 25/32-in. head and medium diamond point.

roofing fastener—See purlin nail.

roofing nail*, asphalt shingle nail, corrugated roofing nail, sheet roofing nail—bright or galvanized, plain-shank, barbed or threadred, regular-stock-steel, 3/4 by 0.092 to 3 by 0.148-in. nails with flat, checkered, large, reinforced, umbrella lead or cast-lead 3/4 to 9/16-in. head and medium or long diamond or needle point, often provided with lead conical neoprene or flat plastic washer. Also, aluminum-alloy, plain-shank or helically threaded, 3/4 by 0.120 to 2 1/4 by 0.150-in. nails with flat or checkered 3/8 to 3/16-in. head and medium diamond or needle point, often provided with conical neoprene washer. (See cap nail.)

scaffolding nail—See double headed nail.

screw nail, screw nail, screw grip nail, screw shank nail, screw shank nail, screw thread nail—terms applied to helically threaded nail and screw-threaded nail. (See thread.)

self-furring nail—galvanized, regular-stock-steel, 1 1/4 to 2 1/2 by 0.106-in. nails with 3/8-in. flat head, medium diamond point, and washer or spacer on shank; for fastening reinforcing wire mesh and spacing it from nailing member.

shade bracket nail—bright, regular-stock-steel, 3/4 to 1 by 0.080 or 0.092-in. nails with slightly countersunk 1/2 or 1 3/8-in. head and needle point.

shake nail, cedar shake or shingle nail, wood shake face nail—enameled (baked-lacquer finished), galvanized, regular-stock-steel, plain shank or annularly threaded, aluminum-alloy, plain shank or helically threaded, or stainless-steel, annularly threaded, 1 1/2 by 0.080 to 2 1/2 by
0.092-in. nails with flat ⅛ to ¾-in. head and medium diamond point. Also, aluminum-alloy 1½ by 0.086 to 1½ by 0.092-in. nails with flat ⅛-in. head and blunt diamond point. Also, aluminum-alloy, annularly threaded, 1½ and 2 by 0.099-in. nails with special type of thread and with flat slightly countersunk ⅞-in. head and long needle point; for fastening cedar shakes to fiberboard nail-base sheathing.

sheathing nail—See common nail, threaded common nail, diaphragm nail, fiberboard nail, gypsum-sheathing nail, hardboard nail.
sheathing/siding nail—stainless-steel, annularly threaded, 1½ by 0.120-in. nail with slightly countersunk ¾-in. head and sharp medium diamond point.
sheet-metal nail—nail stamped out of sheet metal and formed to desired shape. (See roofing nail.)
sheet-roofing fastener nail—See purlin nail.
sheet-roofing nail—See roofing nail.
shingle-backer nail—See shake nail.

shingle nail*—wood-shingle nail—bright or galvanized, regular-stock-steel, plain-shank or annularly threaded, 1½ by 0.076 to 2 by 0.106-in. nails with flat ⅜ to ⅞-in. head and medium or blunt diamond point. Also, bright or colored (baked-lacquer finished), aluminum-alloy, plain-shank or helically threaded, ⅜ by 0.080 to 1½ by 0.099-in. nails with flat ⅜ to ⅞-in. head and medium or blunt diamond point. Also, aluminum-alloy, annularly threaded, 1½ and 2 by 0.101-in. nails with special type of thread and with flat slightly countersunk ⅞-in. head and long needle point for fastening cedar shingles to fiberboard nail-base sheathing.

asbestos-shingle nail—bright or galvanized, regular-stock-steel, annularly threaded, 1 to 2 by 0.113-in. nails with flat 1⅜-in. head and long diamond or needle point. Also, aluminum-alloy, helically threaded, 1½ to 2½ by 0.099 to 0.135-in. nails with smooth or striated flat ⅜ to ⅞-in. head or ⅛ to ⅞-in. casing head and medium diamond or needle point. Also, aluminum-alloy, annularly threaded, 1½ and 2 by 0.101-in. nails with special type of thread and with flat slightly countersunk 0.190-in. sized head and long needle point; for fastening asbestos shingles to fiberboard nail-base sheathing.

asphalt-shingle nail—See roofing nail.
siding nail*—See brick-siding nail, hardboard nail, roofing nail, sheathing/siding nail.

aluminum-siding nail—plain-shank or helically threaded, aluminum-alloy 1 by 0.099 to 2½ by 0.135-in. nails with flat ¼ to ⅜-in. head and medium diamond point.
asbestos-siding face nail—bright, colored (baked-lacquer finished) or galvanized, regular-stock-steel, hardened-steel, bronze, aluminum or stainless-steel, annularly threaded, file-grip or screw-thread, ⅛ by 0.080 to 2 by 0.105-in. nails with smooth or striated flat ⅛-in. or button head and medium diamond or needle point.

common siding nail—bright or colored (baked-lacquer finished), galvanized, regular-stock-steel or hardened-steel, plain-shank or threaded, 1½ by 0.080 to 3 by 0.128-in. nails with flat ½ to ⅜-in. head and medium diamond point.
corrugated-siding nail—See roofing nail.
hardboard-siding nail—See hardboard nail.
insulated-siding nail—bright or colored (baked-lacquer finished) aluminum-alloy, 1½ by 0.113 to 2½ by 0.135-in. nails with flat ⅜ to ⅞-in. head and medium diamond point.
insulating-siding nail—See brick siding nail.
wood-siding nail—bright and colored (baked-lacquer finished), plain-shank or helically threaded, aluminum-alloy, 1½ by 0.106 to 2½ by 0.148-in. nails with ⅛ to ½-in. casing or ⅛ to ½-in. sinker head and medium or blunt diamond point. Also, bright or colored (baked-lacquer finished), stainless-steel, annularly threaded, ² to ²¼ by 0.083 and 0.095-in. nails with slightly countersunk ½-in. head and medium diamond point. (See common siding nail.)
sinker*—bright or coated, slender, regular-stock-steel, 1½ by 0.067 to 5½ by 0.244-in. nails with ⅛ to ½-in. sinker head and medium diamond point, with diamond of head smaller than that of cooler and common nail of same designation.
slatting nail*—galvanized, regular-stock-steel, 1 by 0.106 to 2 by 0.148-in. nails with slightly countersunk ⅛ to ½-in. flat head and medium diamond point. Also, aluminum-alloy, ½ by 0.106 to 1½ by 0.135-in. nails with large flat ⅛ to ½-in. head and medium diamond point. Also, solid copper, ½ by 0.109 to 3 by 0.148-in. nails with large flat head and medium diamond point.
slender, slim nail—nails with Shank diameter usually at least one gage smaller than common nails of same length.
smooth-edge carpet plywood strip nail—hardened-steel, 1½ by 0.105-in. nail with countersunk flat ⅛-in. head and long diamond point.
square-wire nail—bright, diagonally barbed, square-wire, regular-stock-steel, 2 by 0.113 to 4 by 0.192-in. common nails with ⅛ to ¼-in. flat head and medium diamond point; also, 2 by 0.099 and 2½ by 0.113-in. box nails with ¼ and ¼ to ½-in. flat head and medium diamond point; also, 2 by 0.091 and 2½ by 0.109-in. finish nails with 0.124 and 0.131-in. flat head and medium diamond point; also, ½ by 0.131-in. truss nail with ½-in. flat head and medium diamond point.

stout nail—nails with Shank diameter usually at least one gage larger than common nails of same length.

straight nail—nail not bent or bowed.
strap nail—bright, regular-stock-steel, 1½ by 0.092 to 2 by 0.113-in. nails with oval ⅛ to ⅜-in. head and short diamond point.
straw—See purlin nail.
strip nail—steel, 1¼ to 2½-in. nails spot welded to disposable metal strip that feed nails into nailing machine provided with staple-type magazine. During punching of nail from strip, small washer is formed under head. Also, nail stored in special strip to serve as magazine for feeding nailing machine.
subflooring nail—See threaded sinker (annularly threaded), diaphragm nail.
T nail—bright, etched, coated, galvanized, aluminum-coated, plastic-coated, knurled or annularly threaded, stiff-stock or aluminum-alloy, round-wire, 1 by 0.080 to 2½ by 0.131-in.
nails of T shape with \( \frac{3}{16} \) or \( \frac{17}{64} \)-in. round, square or oval-finish head of sinker, with or without heavy fillet, and with diamond or chisel point; driven with special nailing machine provided with staple-type magazine.

**threaded nail**
- **threaded common nail**, **threaded nail**, **threaded sinker**, **n**—bright or galvanized, regular-stock-steel, stiff-stock or hardened-steel, annularly or helically threaded, 1 by 0.072 to 6 by 0.262-in. nails with flat \( \frac{3}{16} \) to \( \frac{1}{16} \)-in. head and 1\( \frac{1}{8} \) by 0.072 to 5\( \frac{1}{4} \) by 0.238-in. sinkers with \( \frac{1}{64} \) to \( \frac{1}{8} \)-in. sinker head and medium diamond point.
- **threaded shear-resistant nail**—stout, short, helically threaded, 1\( \frac{1}{2} \) to 2\( \frac{1}{2} \) by 0.135 and 0.148-in. nails with 0.135-in. collar and sharp, blunt, or medium diamond point.
- **tile nail**
  - **acoustical-tile nail**—slender, electroplated, regular-stock-steel or stiff-stock, 1 to 1\( \frac{3}{4} \) by 0.062-in. nails with \( \frac{1}{4} \)-in. projection head with 0.135-in. collar and sharp, blunt, or medium diamond point.
  - **asbestos-tileboard nail**—stainless steel or other nonferrous metal nails with casing or oval head. (See also asbestos-board nail.)
  - **roofing-tile nail**—galvanized, regular-stock-steel, 5 to 7 by 0.148-in. nails with flat \( \frac{1}{16} \)-in. head and medium diamond point.
- **tileboard nail**—See asbestosboard nail, fiberboard nail, insulation building-board nail.
- **toothed nail**—flat, L-shaped, \( \frac{1}{2} \) to 1\( \frac{1}{2} \)-in. cleats, sheared from 16-gage steel sheet; provided with toothed serrations along narrow sides of long shank and with slightly tapered, dull point; driven with special nailing machine provided with staple-type magazine.
- **trim nail**—See moulding nail.
- **trunk nail**—bright, regular-stock-steel, \( \frac{1}{2} \) to 1\( \frac{1}{4} \)-in. nails with rivet or oval head and extra long “V” point.
- **trussed rafter nail**—See threaded nail.
- **tubing nail**—See conduit nail.
- **twisted nail**—helically twisted, squarewire, \( \frac{1}{2} \) by 0.072 to 6 by 0.250-in. drivescrew nails, usually of tempered stiff-stock, with flat or countersunk head and medium diamond point, with crest diameter being referred to as diameter.
- **twist nail**—slender, copper or aluminum nails with flat head and medium needle point for twist clinching, that is, for having part of nail shank twisted to form a clinched point.
- **underlay nail, underlayment nail**—bright, regular-stock-steel, stiff-stock or hardened-steel, annularly threaded, 1 by 0.080 to 3 by 0.148-in. nails with flat or slightly countersunk \( \frac{1}{16} \) to \( \frac{1}{16} \)-in. head and medium diamond point.
- **upholstery nail**—bright, regular-stock-steel, two-piece nails with extra-large specially formed head and medium diamond or needle point.
- **“V” nail**—headless nails with central V-shaped slot at head end.
- **veneer-box nail**—coated, regular-stock-steel, 1\( \frac{1}{2} \) by 0.080-in. nail with flat \( \frac{1}{4} \) or \( \frac{1}{4} \)-in. head and medium needle point.

**wagon nail**—annealed, barbed, regular-stock-steel nails with round, oval, cone, flat countersunk, or steeple head and medium diamond point.

**wallboard nail**—slender, colored (baked-lacquer finished), regular-stock-steel or hardened-steel, smooth or annularly threaded, 1\( \% \) by 0.062 to 2 by 0.083-in. nails with slightly countersunk 0.109 to 0.181-in. head and medium diamond or long needle point.

**wire nail**—nail manufactured from metal wire or rod.

**wood-heel attaching nail**—bright, regular-stock-steel, annularly threaded or helically threaded, \% by 0.054 to \% by 0.072-in. nails with slightly countersunk flat head and medium or long diamond point.

**wood-heel top-lift nail**—bright, regular-stock-steel, \( \frac{1}{2} \) by 0.041 to \( \frac{1}{2} \) by 0.048-in. nails with flat or brad head and long diamond point.

**wood-lath nail**—blued, regular-stock-steel, 1 and 1\( \frac{1}{4} \) by 0.054 and 0.072-in. nails with flat \( \frac{1}{6} \) to 1\( \frac{1}{6} \)-in. head and medium diamond point.

**NAIL HEADS**

- **head**—upset or deformation of shank, usually at or near end of shank opposite point end; formed during manufacture of nail to provide area to be struck by hammer during driving and to offer bearing resistance (see Fig. 1).
- **angle**—on countersunk head, total included angle formed by...
conical underportion or bearing surface.

ball head—spherical head.

bearing surface—underside of head in contact with nailed member.

bent head—wire bent and upset to form head. (See hook head.)

brad head—small-diameter, deep, circular, barrel-shaped head with flat or concavely cupped top surface, as found on finishing nails and common brads for countersinking where concealment is important.

crimped head—head with undulating or pronged rim, or both.

cup head with raised lines in cup forming crossed head

circular head, having flat, circular, parallel top and bearing surfaces and slightly rounded edge or rim.

head height—total height of head; the sum of all head elements measured parallel to nail axis; for practical purposes, measured from top of fillet to top of head.

head length—on a hook-head or similarly headed nail, projected distance between shank and extremity of head.

headless—nail without upset or bend at head end.

head rim—peripheral part of head.

hook head—head, usually flattened; formed by bending wire at right angle to shank; resulting in fastener shaped like “L.”

large head—larger than standard head, usually more than 3 to 3 1/2 times shank diameter.

lead head, cast lead head, compressed lead head—lead encasement pressed or cast onto or around small 9/32-in. steel head, or both.

lettered head—head with raised or depressed, identifying letter or letters on top surface of head.

marking, marker head—See lettered head, numeral head.

nub head—head with protruding knob. (See washer head.)

numeral head—head with raised or depressed, identifying number or numbers on top surface of head.

oval head, oval rivet head—circular head having convex top surface, with its height smaller than its radius.

pan head—flat head with rim having rounded upper edge and squared lower edge, usually slotted.

projection head—flange or collar spaced at short distance from end of wire, with wire projecting from upper side of flange or collar forming part of head and wire projecting from other side of flange or collar forming the Shank. (See gudgeon.)

rim thickness—thickness of peripheral part of head, measured parallel to nail axis.

rivet head—See oval head.

rose head—pyramidal head with four triangular faces meeting at common vertex, having a square, rectangular, or circularized flat bearing surface.

round head—circular head having convex top surface with height equal to its radius.

saucer head—circular, cupped head with concave top surface and convex bearing surface.

screw head—See slotted head.

sinker head—flat, slightly countersunk (115° to 130°) head, as found on sinkers and corker nails; smaller in diameter than head on cooler and common nails.

slotted head—head provided with cut or struck slot for insertion of screwdriver or to simulate head of wood screw.

spring head—See cupped oval head, umbrella head.
star head—slightly raised pyramidal head with multiple triangular faces meeting at common vertex, having a polygonal or circularized flat bearing surface.

steeple head—See cone head.

striated head—head with parallel ridges and grooves to identify high-density fiberboard nail.

taper—included angle of countersink.

umbrella head—extra-large cupped oval head, provided with slight projection of nail shank above head to provide striking surface during driving.

upset head—metal slightly upset, with deformed portion serving as head.

washer head—head with washer-like flange to serve as bearing surface for head. (See nub head.)

NAIL POINTS

point—end of shank opposite head, usually tapered; formed during manufacture of nail to facilitate driving (see Fig. 2).

included angle—angle between the sides of the point in the longitudinal section through the nail in the direction perpendicular to the point sides.

ballistic point—bullet-shaped point.

ball point—spherical point on Shank of nail, having a diameter equal to that of shank.

beveled square point—extremity of nail shank opposite head sheared obliquely to shank axis. (See sheared-bevel point.)

blunt chisel point, short chisel point—chisel point with large included angle.

blunt diamond point, short diamond point—diamond point with large included angle.

blunt point, short point—point with large included angle; designed to punch and not to split. (See dull point.)

blunted-point—point end of nail purposely dulled by nail user prior to driving of nail. (See dull point.)

brad-clinched point—pointed end of nail, having been driven through member, flattened and bent sideways to a limited extent when striking flat anvil plate.

butterfly point—a defective point with one or two thin fins projecting. (See burr.)

chisel point—point with two major planes forming “V” and pair of minor planes on each flank; forming hexagonal cross section.

clinch point—end of wire flattened or notched or both for easy clinching when striking anvil plate or “nail buck.” (See self-clinching.)

clinch point—pointed end of nail, having been driven through member bent sideways. (See brad-clinched point, J-clinched point, plate-clinched point.)

cupped point—Incomplete needle point; resulting from breaking of tip of point during forming.

diamond point—symmetrical point having four approximately equal bevelled planes forming a pyramid; its length measured along cut edge of point. Usually applied unless otherwise specified.

duckbill point—end of wire flattened to thin elliptical cross section having sharp periphery, in appearance somewhat like bill of duck, to facilitate clinching at predetermined point, slight transverse depression may be formed across point.

dull point—end of point rounded in contrast to being sharp.

fin—thin projection from cut edge of point, a defect. Occasionally found on rim of head.

“fish-mouth” point—incomplete chisel wedge point with two narrow ridges at end, a defect resulting from premature breaking of wire during forming.

J-clinched point—pointed end of nail having been driven through member against curved anvil plate, bent sideways and driven back into member.

length—distance between beginning and end of point, measured along edge of point.

long point—point with 20° or smaller included angle for 0.040 to 0.065-in. wire diameter; 25° or smaller included angle for 0.072 to 0.225-in. wire diameter; 30° or smaller included angle for 0.250 to 0.325-in. wire diameter.

medium point—point with 28° to 35° included angle for 0.040 to 0.065-in. wire diameter; 32° to 38° included angle for 0.072 to 0.225-in. wire diameter; 37° to 44° included angle for 0.250 to 0.325-in. wire diameter.

needle point—point forming circular cone.

offset point—See side point.

peaned point—point formed like that usually found on rivets.

pencil point—long needle point.

pilot point—point of threaded nail with plain portion of shank between top of point and threaded portion of shank.
plate-clinched point—pointed end of nail, having been driven through member against anvil plate, bent sideways.
pointed—provided with sharp point.
pointless—See sheared-square point.
regular point—denoting medium diamond point.
sharp point—end of point being keen, instead of being slightly rounded or dull.
sheared point—See sheared-bevel point, sheared-square point.
sheared-bevel point—one directional point having one flat surface; formed by shearing nail wire off at angle to shank axis, inducing nail to diverge from straight penetration unless countermeasures are introduced.
sheared-square point—extremity of nail shank opposite head end of nail sheared at right angle to shank axis.
short point—point with 40° or greater included angle for 0.040 to 0.065-in. wire diameter; 45° or greater included angle for 0.072 to 0.225-in. wire diameter; 55° or greater included angle for 0.250 to 0.325-in. wire diameter.
side point—an eccentric nonsymmetrical point.
square point—sheared square point; also known as no point or square-cut point.
tapered wedge point—point with two major planes forming “V” and with single minor plane on each flank; forming rectangular cross section.
truncated point—needle point with its tip sheared square.
 wedge point—point with two convergent planes forming “V.”

NAIL THREADS

thread—annular and helical and, sometimes, longitudinal deformations rolled onto shank; in general, with deformations passing entirely around body; usually resulting in expanded ridges and depressions, larger and smaller, respectively, than wire diameter. (See knurled.)
angle—See lead angle.
annular thread—multiple ring-like threads rolled completely around shank in planes perpendicular to nail axis; having a lead angle of zero degree.
buttress-type thread—thread with flank on head side of crest almost perpendicular to nail axis; while flank on point side of crest is noticeably inclined.
crest—outermost part of thread, joining flanks. (See double crest.)
crest diameter—twice the distance between nail axis and crest, measured perpendicular to nail axis. Thread crest diameters for given shank diameters:

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double crest—crest having two ridges separated by slight depression.

file thread, file-grip thread—large number of fine, closely spaced helical threads, with large or extra large lead angle, rolled onto shank. Usually applied to certain aluminum asbestos-shingle face nails.
“fish-hook-like” thread—See buttess-type thread.
flank, side—surface between root and crest; “leading” flank being on point side of crest and “following” flank being on head side of crest.
flattened thread, flat-bottom thread—thread having flat root. Flattened thread occasionally referring to flattened thread crest.
flute—helical and, sometimes, vertical deformation rolled onto shank.
height—distance between root and crest, measured perpendicular to nail axis.
helical thread—continuous multiple helical depressions rolled onto nail shank with resulting expansion approximately equal to depression. Unless otherwise specified, medium lead angle is implied.

helix angle—See lead angle.

incomplete thread—thread not fully formed.
lead angle, helix angle—angle made by helix of thread with plane perpendicular to nail axis; measured at pitch line; small lead angle usually refers to less than 20°; medium lead angle usually refers to 55° to 65°; large lead angle refers to 65° to 75°; extra large lead angle refers to 80° to 85°.
longitudinal thread—multiple flutes parallel or nearly parallel to nail axis, rolled onto nail shank, having a lead angle of or closely approaching 90°.
pitch diameter—for all practical purposes, the diameter of the smooth shank prior to threading.
pitch line—line parallel to nail axis located at distance equal to one-half of pitch diameter from nail axis.
ratchet thread—type of buttress thread, usually annular for engagement with nailing channels, retaining clips, etc.
rating thread, ring-bar thread, ring-groove thread, ring-grip thread, ring-shank thread—See annular thread.
root—innermost part of thread, rounded or flattened; joining flanks of adjacent threads.
root diameter—twice the distance between nail axis and root, measured perpendicular to nail axis.
rounded thread, round-bottom thread—thread with rounded root extending to pitch line. Rounded thread also referring to rounded thread crest.
screw, screw-grip thread, screw-shank thread, screw-shank thread, screw thread—See helical thread, screw thread.
screw thread—helical thread with small lead angle rolled onto nail Shank.
shoulder—edge, when present, at junction of thread crest and flank. If double crested, primary shoulder is nearer head and should be equal to or larger in diameter than secondary shoulder, which is closer to point.
space—distance between centers of adjacent crests, measured perpendicular to crests.
spiral thread—mismomer for helical thread.
symmetrical thread—thread where following flank is a mirror-image of leading flank about line through crest and perpendicular to nail axis.
“V” thread—thread with leading flank of one thread intersecting with following flank of adjacent thread at thread root.
vertical thread—misnomer for longitudinal thread.

width—See spacing.

MISCELLANEOUS TERMS

acid-etched—treated in an acid bath, usually phosphoric, to provide a rough surface.
aluminized—dipped in molten aluminum for coating purposes resulting in smooth, continuous, and adherent aluminum coating.
annealed—heated and subsequently cooled to provide increased ductility.
anodized aluminum—natural-colored or surface-colored aluminum having increased anodic corrosion resistance.
barbed—shank provided with repetitive, shallow or deep, symmetrical or nonsymmetrical, cross-wise or oblique, diagonal or perpendicular indentations and ridges, excluding grip marks.
barrel-galvanized—See hot-galvanized.
blued—heated to result in oxidized bluish surface of steel nail.
bonderized—phosphate coated. (See parkerized.)
bright—term applied to nails with natural bare finish resulting from cleaning of nails which have not undergone treatments affecting finish, such as hardening, bluing, coating, plating, etching, painting, etc. Also applied to polished appearance after plating.
bright finish—non-coated wire finish.
bulge—doughnut-like protrusion perpendicular to nail shank below nail head.
burr—thin, wing-like protrusion perpendicular from side or edge of point or underside of top of head; defect formed during pointing or heading process and intended to be removed during manufacturing process. (See whisker.)
carton—See packaging.
case-hardened, surface-hardened—surface of steel nail case-hardened and subsequently hardened, by suitable heat treatment, leaving a soft core.
cement-coated—surface coated by tumbling or immersion in natural resin or shellac to produce a limited temporary bond, leaving a soft core.
clad—surface sheathed.
cleaned—oil and other foreign matter removed from surface by tumbling with sawdust or by chemical process.
clearance—plain section of shank between head and shank deformation (disregarding gripmarks).
clinch—point end bent sideways to provide increased holding power or to eliminate protrusion of point end of excessively long fastener, or both.
coated—covered fully or partially with natural resin or conversion coating to provide ease of driving, increased holding power, or corrosion resistance, or a combination of these.
cohered—fastened together in strip form, usually with adhesive. (See collated.)
collated—fastened next to each other in strip form. (See cohered.)

colored—See anodized, blued, enameled, lacquered, painted.
coppered, copper-washed—all surfaces chemically plated with copper, usually by chemical rather than electrolytic process. (See electroplated.)
corrosion-resistant—term used to describe a material or treatment designed to inhibit corrosion. (See rustproof.)
count—approximate number of nails per pound influenced by sizing of individual elements.
deformed—See mechanically deformed.
diameter—length of longest straight line through center of cross section of wire from which nail is formed. Diameter of pointed nail is that immediately below the grip marks. Diameter of nail with roll-threaded shank is that of wire or nail prior to being threaded. In the case of fluted, roll-grooved, and twisted nails, formed diameter refers to crest diameter. Diameter does not include coating except cladding. (See thread-crest diameter.)
die marks—See grip marks.
dipped—dipped in bath of molten zinc for coating purposes, with excess zinc removed; resulting in coating essentially free from blisters, lumps, gritty areas, acid spots, dross warts, and flux.
electro-galvanized, electro-zinc plated—See zinc-plated.
electroplated—surface provided with usually thin electrochemical deposit of brass, cadmium, copper, nickel, tin, zinc, etc., as a result of immersion in electrolytic bath.
enameled—coated with enamel of desired color and often baked.
etched—cleaned of grease and oil, with slightly dulled, microscopically roughened surface, usually by a chemical process.
fillet—curved intersection of head and shank, specified by its radius.
fin—See burr.
flake-galvanized—See hot-galvanized.
fluted—deformed with continuous, symmetrical, helical, or longitudinal depressions. Four or five of these flutes are usually formed onto wire from which fluted nail is made, in contrast to threading where shapes are rolled onto nail shank in a thread-rolling process. Flutes resulting from this manufacturing process extend the full length of the nail shank. (See roll-grooved and mechanically deformed.)
flutes—continuous symmetrical depressions along nail shank.
formed—See mechanically deformed.
galvanized—See zinc-coated.
gauge, gage—instrument used to measure wire diameter. (See wire gage.)
grip mark, griepe mark, gripper mark—indentations and ridges along shank, usually near head, made by gripping devices that hold wire during heading; often used with other markings to classify nail manufacturer.
grooved—general term sometimes used to denote threaded, fluted, twisted, knurled, barbed, etc.
gummed—See coated.
hardened—heat-treated medium-carbon or medium-high-carbon-steel, with treating process resulting in toughened
nail with greater stiffness at high flexural loads. (See
heat-treated.)

heat-treated—heated above critical temperature and subse-
quently quenched, which may be followed by tempering for
the purposes of obtaining certain desirable conditions or
properties, such as hardness, toughness, and stiffness at high
flexural loads.

high-carbon steel—See steel grades.

hot-dipped, hot-dip galvanized, hot-dipped zinc-coated—See
dipped.

hot-galvanized, barrel-galvanized, flake-galvanized,
tumbler-galvanized, wean-galvanized—zinc coating ap-
plicated in heated tumbling barrel containing zinc-flakes.

identification—See grip mark.

japanned—tumble-pointed.

keg, nail keg—synonymous with 100 lb (45.36 kg) of nails.
Round, bulging container for bulk nails, made of wooden
staves, steel hoops, and flat heads, usually holding 100 lb of
nails. Terms no longer in common usage.

knurled—loose term used to denote threaded, fluted, or
grooved parallel or nearly parallel to nail axis with defor-
mations not passing around body (see thread); also, barbed
or deformed in repetitive pattern along surface.

lacquer-finished—coated with lacquer and often baked, usu-
ally in such colors as to match or blend with color of item to
be fastened.

length—distance measured parallel to shank axis from maxi-
mum diameter of bearing surface of head to extreme end of
point; except in case of cement-coated, brad-headed, and
oval-countersunk-headed nails where measurement includes
complete head.

Discussion—In evaluating nail performance, length is mea-
sured to and including one third of length of point.

liquor finish—very thin wire coating produced by wire im-
ersion in metallic salts, usually copper, offering very
limited corrosion resistance.

low-carbon-steel—See steel grades.

machine quality—term applied to nails manufactured with
closer tolerances than usual and selected for close adherence
to specification and freedom from foreign matter.

mechanically deformed—nails with roll-threaded or formed
shanks to improve holding power.

roll-threaded—with helical, annular, or longitudinal defor-
mations rolled on fastener shank.

formed—with barbed, angular, serrated, longitudinally or
helically fluted, longitudinally or helically roll-grooved or
twisted deformations formed on wire from which nail is
made.

mechanically plated, peen-coated, peen-galvanized—
covered with coat of zinc through peen-coating, that is, by
tumbling in a container holding powdered zinc and numer-
ous glass beads.

medium-high carbon—See steel grades.

medium-low carbon—See steel grades.

multi-ribbed—See thread, vertical.

oil-tempered—heated above the critical temperature,
quenched in oil, and tempered.

oxidized—darkened or dulled by surface treatment or by the
natural oxidizing of metal.

pack-hardened, pack-carburized—See case-hardened.

painted—coated with paint or plastic by dipping or barrel-
tumbling.

parkerized—chemically treated to provide iron and steel with
dark corrosion-resistant protective coating by boiling in
solution of manganese diphosphonate and subsequently
applying coating of paraffin oil.

peen-coated, peen-galvanized—See mechanically plated.

penny size, penny weight—denoting length of nail, indicated
by “d” (not indication of diameter). Because of standardiza-
tion of sizes of common nails, sinkers, and cooler nails,
penny weight denotes, in addition to length, the head and
shank diameter of these nails. For other nail types, sizes are
referred to by length and diameter.

phosphate-coated, phosphatized—chemically treated to pro-
vide iron and steel with gray protective ferric-phosphate
coating; to provide increased nail holding power by surface
roughening.

pilot—plain-shank section between point and threaded portion
of shank.

plain-shank—term applied to nail without shank deforma-
tions, disregarding grip-marks.

plain steel—bright steel.

plastic coated—covered fully or partially with polymer to
provide ease of driving, increased holding power, or corro-
sion resistance, or a combination of these.

plated—See electroplated.

polished—See tumbled.

quench-hardened—See hardened.

resin-coated—covered with natural resin to provide ease of
driving, increased holding power, or corrosion resistance, or a
combination of these.

roll-grooved, rolled-grooved—provided with four or more
continuous symmetrical, longitudinal or helical flutes; result-
ing from roll-grooving of round wire prior to heading and
pointing of nail. Flutes resulting from this manufacturing
process extend all the way from head to point (See fluted.)

round shank—term applied to nail with shank of circular
cross section, made from round wire.

rustproof—made of nonferrous material or protectively
covered, plated, galvanized or aluminized. (See corrosion-
resistant, rust-resistant.)

rust-resistant—term used to describe a material or treatment
designed to inhibit rusting; not synonymous with rustproof.

self-clinching—term applied to nail with point or shank
designed in such a way that nail clinches automatically while
fully driven.

self-spreading—term applied to nail with split shank designed
in such a way that two or more legs penetrate material in
divergent directions.

serrated—See barbed.

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3 Annual Book of ASTM Standards, Vol 01.05.
shank—main body of nail extending from head to point.

shank, formed or deformed—See barbed, fluted, grooved, knurled, threaded, or twisted.

shank diameter—See diameter.

shear-resistant—See threaded shear-resistant nail.

smooth shank—See plain shank.

square shank—term applied to nails with shank of essentially square cross section with or without longitudinal flutes or diagonal barbs; usually found on nails made from square wire. Shank-diameter of nails measured across diagonal (see diameter).

steel grades—steel classified by carbon content. The following grades are generally used for wire or raw material purchase; but do not restrict nails to specific analysis. When the steel grade is referred to in the definition of a nail type, it is intended only as a general indication of the likely material used. Any steel of suitable analysis may be used in nail manufacture unless specified otherwise in the product standard.

low-carbon steel— a grade of steel (see Specification A 510 for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel) wherein the maximum of the carbon range is up to and including 0.15 %.

medium low-carbon steel—a grade of steel (Specification A 510) wherein the maximum of the carbon range exceeds 0.15 % up to and including 0.23 %.

medium high-carbon steel—a grade of steel (Specification A 510) wherein the maximum of the carbon range exceeds 0.23 % up to and including 0.44 %.

high-carbon steel— a grade of steel (Specification A 510) wherein the maximum of the carbon range exceeds 0.44 %.

stock steel—standard steel of regular or stiff stock.

regular—bright, non-hardened, usually low or medium low-carbon steel.

stiff—bright, non-hardened, usually medium low or medium high-carbon steel, having higher hardness, toughness, and stiffness than regular steel.

tempered—reheated after hardening to some temperature below the critical range and subsequently cooled to increase toughness and ductility.

threaded—annular, helical or longitudinal, symmetrical or nonsymmetrical, flat-bottom or round-bottom deformations with single or double crest shoulders and with rounded or flat flanks; formed onto nail shank after heading by passing through roll-threading dies. (See mechanically deformed, knurled, thread.)

tinned—See electroplated, wash-tinned.

tolerances—dimensional limitations established by manufacturers, customers, associations, and government agencies.

tumbled—cleaned and polished by agitation in rotating drum containing polishing compound, such as sawdust or other burnishing media.

tumbler-galvanized— See hot-galvanized.

twisted—provided with four or more continuous, symmetrical, helical deformations; resulting from twisting of square nail wire about its own longitudinal axis prior to heading and pointing of nail. Helical deformations resulting from this manufacturing process extend all the way from head to point, thus preventing inclusion of clearance between head and thread.

water-hardened—quenched in water after heating to critical temperature.

wean-galvanized—See hot-galvanized.

whisker—two triangular pieces of metal formed during cutting of nail point.

wire gage—measure used to describe, by system of arbitrary numbers, diameter of shank or wire from which nail is made. Because several systems of gage designations are in use, reference to particular gage system should be indicated. (See Table 1.)


zinc-plated—surface provided with usually thin electrochemical deposit of zinc as a result of immersion in electrolytic bath or with mechanical deposit of zinc as a result of peen coating.
APPENDIX

(Nonmandatory Information)

X1. METRIC EQUIVALENTS

X1.1 The metric units listed in Table X1.1 are for information only and are not intended to be used for ordering purposes.

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<td>0.120</td>
<td>3.050</td>
<td>0.219</td>
<td>5.56</td>
<td>7⁄16</td>
<td>10.86</td>
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<tr>
<td>0.128</td>
<td>3.250</td>
<td>0.225</td>
<td>5.72</td>
<td>15⁄64</td>
<td>11.90</td>
<td></td>
</tr>
<tr>
<td>9⁄64</td>
<td>3.570</td>
<td>15⁄64</td>
<td>5.95</td>
<td>1⁄2</td>
<td>12.70</td>
<td></td>
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<tr>
<td>0.148</td>
<td>3.760</td>
<td>1⁄4</td>
<td>6.35</td>
<td>17⁄64</td>
<td>13.50</td>
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<tr>
<td>0.155</td>
<td>3.940</td>
<td>0.262</td>
<td>6.66</td>
<td>9⁄16</td>
<td>14.29</td>
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<tr>
<td>5⁄52</td>
<td>3.970</td>
<td>17⁄64</td>
<td>6.75</td>
<td>3⁄4</td>
<td>15.88</td>
<td></td>
</tr>
<tr>
<td>11⁄64</td>
<td>4.370</td>
<td>9⁄32</td>
<td>7.14</td>
<td>15⁄16</td>
<td>17.46</td>
<td></td>
</tr>
</tbody>
</table>

TABLE X1.1 Metric Conversions

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Standard Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners

This standard is issued under the fixed designation F 568M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers chemical and mechanical requirements for nine property classes of carbon and alloy steel externally threaded metric fasteners in nominal thread diameters M1.6 through M100 suited for use in general engineering applications.

1.2 This specification does not cover dimensional requirements for fasteners of any property class. When referencing this specification for procurement purposes, it is mandatory that size, type, style, and any special dimensions of the product be additionally specified.

1.2.1 In case of any conflict in requirements, the requirements of the individual product specification shall take precedence over those of this general specification.

1.2.2 The purchaser may specify additional requirements which do not negate any of the provisions of this general specification or of the individual product specification. Such additional requirements, the acceptance of which are subject to negotiation with the supplier, must be included in the order information (see Section 3).

1.3 Requirements for seven of the nine property classes, 4.6, 4.8, 5.8, 8.8, 9.8, 10.9, and 12.9, are essentially identical with requirements given for these classes in ISO 898-1. The other two, 8.8.3 and 10.9.3, are not recognized in ISO standards.

1.4 Classes 8.8.3 and 10.9.3 bolts, screws, and studs have atmospheric corrosion resistance and weathering characteristics comparable to those of the steels covered in Specification A 588. The atmospheric corrosion resistance of these steels is substantially better than that of carbon steel with or without copper addition. See 5.2. When properly exposed to the atmosphere, these steels can be used bare (uncoated) for many applications.

1.5 When agreed on by the purchaser, Class 5.8 fasteners may be supplied when either Classes 4.6 or 4.8 are ordered; Class 4.8 may be supplied when Class 4.6 is ordered; Class 8.8.3 may be supplied when Class 8.8 is ordered; and Class 10.9.3 may be supplied when Class 10.9 is ordered.

1.6 The product size range for which each property class is applicable is given in Table 1 and Table 2 on chemical composition requirements, and the mechanical requirements table (see Table 3).

1.7 Appendix X1 gives conversion guidance to assist designers and purchasers in the selection of a suitable property class.

1.8 Appendix X2 explains the significance of the property class designation numerals.

2. Referenced Documents

2.1 ASTM Standards:
A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
A 307 Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength
A 325 Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
A 325M Specification for High-Strength Bolts for Structural Steel Joints [Metric]
A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
A 449 Specification for Quenched and Tempered Steel Bolts and Studs
A 490 Specification for Heat-Treated Structural Steel Bolts, 150 ksi Minimum Tensile Strength
A 490M Specification for High-Strength Steel Bolts, Classes 10.9 and 10.9.3, for Structural Steel Joints [Metric]
A 574 Specification for Alloy Steel Socket-Head Cap Screws
A 588/A588M Specification for High-Strength Low-Alloy

1 This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.02 on Steel Bolts, Nuts, Rivets and Washers.

*A Summary of Changes section appears at the end of this standard.

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TABLE 1 Chemical Composition Requirements

<table>
<thead>
<tr>
<th>Property Class</th>
<th>Nominal Product Diameter, mm</th>
<th>Material and Treatment</th>
<th>Product Analysis Element (% by weight)</th>
<th>Tempering Temperature, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>C</td>
<td>Mn</td>
</tr>
<tr>
<td>4.6</td>
<td>M5–M100</td>
<td>low or medium carbon steel</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>4.8</td>
<td>M1.6–M16</td>
<td>low or medium carbon steel, partially or fully annealed as required</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>5.8</td>
<td>M5–M24</td>
<td>low or medium carbon steel, cold worked</td>
<td>0.13</td>
<td>0.55</td>
</tr>
<tr>
<td>8.8</td>
<td>M20–M60</td>
<td>medium carbon steel, product is quenched and tempered</td>
<td>0.25</td>
<td>0.55</td>
</tr>
<tr>
<td>8.8</td>
<td>M20–M36</td>
<td>low carbon martensite steel, product is quenched and tempered</td>
<td>0.15</td>
<td>0.40</td>
</tr>
<tr>
<td>9.8</td>
<td>M1.6–M16</td>
<td>medium carbon steel, product is quenched and tempered</td>
<td>0.25</td>
<td>0.55</td>
</tr>
<tr>
<td>9.8</td>
<td>M1.6–M16</td>
<td>low carbon martensite steel, product is quenched and tempered</td>
<td>0.15</td>
<td>0.40</td>
</tr>
<tr>
<td>10.9</td>
<td>M5–M20</td>
<td>medium carbon steel, product is quenched and tempered</td>
<td>0.25</td>
<td>0.55</td>
</tr>
<tr>
<td>10.9</td>
<td>M5–M100</td>
<td>medium carbon alloy steel, product is quenched and tempered</td>
<td>0.20</td>
<td>0.55</td>
</tr>
<tr>
<td>10.9</td>
<td>M5–M20</td>
<td>low carbon martensite steel, product is quenched and tempered</td>
<td>0.15</td>
<td>0.40</td>
</tr>
<tr>
<td>10.9.3</td>
<td>M16–M36</td>
<td>atmospheric corrosion resistant steel, product is quenched and tempered</td>
<td>0.31</td>
<td>0.65</td>
</tr>
</tbody>
</table>

A  For studs only, sulfur content may be 0.33 %, max.
B  At the manufacturer’s option, medium-carbon-alloy steel may be used for nominal thread diameters over M24.
C  For studs only, sulfur content may be 0.13 %, max.
D  Products made using this material shall be specially identified as specified in Section 14.
E  Steel for Classes 10.9, 10.9.3, and 12.9 products shall be fine grain and have a hardenability that will achieve a structure of approximately 90 % martensite at the center of a transverse section one diameter from the threaded end of the product after oil quenching.
F  Carbon steel may be used at the option of the manufacturer for products of nominal thread diameters M12 and smaller. When approved by the purchaser, carbon steel may be used for products of diameters larger than M24, inclusive.
G  Alloy steel shall be used. Steel is considered to be alloy by the American Iron and Steel Institute when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: manganese, 1.65 %; silicon, 0.60 %; copper, 0.60 %; or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99 %, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying elements added to obtain a desired alloying effect.

Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4 in. [100 mm] Thick
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
D 3951 Practice for Commercial Packaging
F 606M Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets [Metric]
F 788/F788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series
F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Requirements

2.2 ISO Standard:
ISO 898-1, Mechanical Properties of Fasteners, Part I, Bolts, Screws, and Studs
2.3 ASME Standards:
B 18.2.3.1M Metric Hex Cap Screws
B 18.2.3.2M Metric Formed Hex Screws
B 18.2.3.3M Metric Heavy Hex Screws
B 18.2.3.4M Metric Hex Flange Screws
B 18.2.3.5M Metric Hex Bolts
B 18.2.3.6M Metric Heavy Hex Bolts
B 18.5.2.1M Metric Round Head Short Square Neck Bolts
B 18.5.2.2M Metric Round Head Square Neck Bolts

3. Ordering Information
3.1 Orders for products referencing this specification shall include the following:
3.1.1 Quantity (number of pieces),
3.1.2 Name of product (that is, type and style of bolt, screw, or stud),
3.1.3 Dimensions, including nominal thread diameter, thread pitch, and length,
3.1.4 Property class,
3.1.5 Zinc Coating—Specify the zinc coating process required, for example, hot dip, mechanically deposited, or no preference (see 4.5),
3.1.6 Other Finishes—Specify other protective finish, if required,
3.1.7 ASTM designation and year of issue, and any special requirements (for example, mechanical requirements, see Tables 3 and 4, or proof load testing, see Tables 5 and 6; stud marking, see 14.2.3; additional testing, see 8).
3.1.9 Test reports if required, see section 13.

4. Materials and Manufacture
4.1 Steel for bolts, screws, and studs shall be made by the open-hearth, basic-oxygen, or electric-furnace process.
4.2 Heading Practice:
### TABLE 2 Chemical Composition Requirements for Classes 8.8.3 and 10.9.3

<table>
<thead>
<tr>
<th>Element</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
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<tr>
<td>Carbon:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.33–0.40</td>
<td>0.38–0.48</td>
<td>0.15–0.25</td>
<td>0.15–0.25</td>
<td>0.020–0.25</td>
<td>0.20–0.25</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.31–0.42</td>
<td>0.36–0.50</td>
<td>0.14–0.26</td>
<td>0.14–0.26</td>
<td>0.18–0.27</td>
<td>0.19–0.26</td>
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<tr>
<td>Manganese:</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.90–1.20</td>
<td>0.70–0.90</td>
<td>0.80–1.35</td>
<td>0.40–1.20</td>
<td>0.60–1.00</td>
<td>0.90–1.20</td>
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<tr>
<td>Product analysis</td>
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<td>0.67–0.93</td>
<td>0.76–1.39</td>
<td>0.36–1.24</td>
<td>0.56–1.04</td>
<td>0.86–1.24</td>
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<td>Phosphorus:</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.040 max</td>
<td>0.06–0.12</td>
<td>0.035 max</td>
<td>0.040 max</td>
<td>0.040 max</td>
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<td>Product analysis</td>
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<td>0.06–0.125</td>
<td>0.040 max</td>
<td>0.045 max</td>
<td>0.045 max</td>
<td>0.045 max</td>
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<tr>
<td>Sulfur:</td>
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<td>Heat analysis</td>
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<td>0.050 max</td>
<td>0.040 max</td>
<td>0.050 max</td>
<td>0.040 max</td>
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<tr>
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<td>0.055 max</td>
<td>0.055 max</td>
<td>0.045 max</td>
<td>0.055 max</td>
<td>0.045 max</td>
<td>0.045 max</td>
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<tr>
<td>Silicon:</td>
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<tr>
<td>Heat analysis</td>
<td>0.15–0.35</td>
<td>0.30–0.50</td>
<td>0.15–0.35</td>
<td>0.25–0.50</td>
<td>0.15–0.35</td>
<td>0.15–0.35</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.13–0.37</td>
<td>0.25–0.55</td>
<td>0.13–0.37</td>
<td>0.20–0.55</td>
<td>0.13–0.37</td>
<td>0.13–0.37</td>
</tr>
<tr>
<td>Copper:</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.25–0.45</td>
<td>0.20–0.40</td>
<td>0.20–0.50</td>
<td>0.30–0.50</td>
<td>0.30–0.60</td>
<td>0.20–0.40</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.22–0.48</td>
<td>0.17–0.43</td>
<td>0.17–0.53</td>
<td>0.27–0.53</td>
<td>0.27–0.63</td>
<td>0.17–0.43</td>
</tr>
<tr>
<td>Nickel:</td>
<td></td>
<td></td>
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<tr>
<td>Heat analysis</td>
<td>0.25–0.45</td>
<td>0.50–0.80</td>
<td>0.25–0.50</td>
<td>0.50–0.80</td>
<td>0.30–0.60</td>
<td>0.20–0.40</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.22–0.48</td>
<td>0.47–0.83</td>
<td>0.22–0.53</td>
<td>0.47–0.83</td>
<td>0.27–0.63</td>
<td>0.17–0.43</td>
</tr>
<tr>
<td>Chromium:</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Heat analysis</td>
<td>0.45–0.65</td>
<td>0.50–0.75</td>
<td>0.30–0.50</td>
<td>0.50–1.00</td>
<td>0.60–0.90</td>
<td>0.45–0.65</td>
</tr>
<tr>
<td>Product analysis</td>
<td>0.42–0.68</td>
<td>0.47–0.83</td>
<td>0.27–0.53</td>
<td>0.45–1.05</td>
<td>0.55–0.95</td>
<td>0.42–0.68</td>
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<td>Vanadium:</td>
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<td>0.020 min</td>
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</tr>
<tr>
<td>Product analysis</td>
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<td></td>
<td>0.010 min</td>
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<td>Molybdenum:</td>
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<tr>
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<td>0.06 max</td>
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</tr>
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<td>0.05 max</td>
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</tr>
<tr>
<td>Product analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A, B, C, D, E, and F are types of material used for Property Classes 8.8.3 and 10.9.3 bolts, screws, and studs. Selection of a composition shall be at the option of the product manufacturer except that sizes M20 and larger shall conform to Composition A or B only.

### TABLE 3 Mechanical Requirements for Bolts, Screws, and Studs

| Property Class | Nominal Diameter of Product | Full Size Bolts, Screws, and Studs | Machined Test Specimens of Bolts, Screws, and Studs | Surface Hardness | Product Hardness |
|----------------|----------------------------|-----------------------------------|-----------------------------------------------|----------------|----------------|----------------|
|                |                            | Proof Load<sup>A</sup> | Tensile Strength, MPa<sup>4</sup> | Yield Strength, MPa<sup>5</sup> | Elongation, % | Reduction of Area, % | Rockwell 30N | Rockwell | Vickers |
|                |                            | Length Measurement Method, MPa | Min | Min | Min | Min | Min | Max | Min | Max | Min | Max |
| 4.6            | M5–M100                    | 225 | 240 | 400 | 400<sup>6</sup> 22 | 35 | ... | B67 | B95 | 120 | 220 |
| 4.8            | M1.6–M16                   | 310 | 340 | 420 | 420<sup>6</sup> 14 | 35 | ... | B71 | B95 | 130 | 220 |
| 5.8            | M5–M24<sup>10</sup>        | 380 | 420 | 520 | 520<sup>6</sup> 10 | 35 | ... | B82 | B95 | 160 | 220 |
| 8.8            | M20–M80                    | 600 | 660 | 830 | 830<sup>6</sup> 12 | 35 | 53 | C23 | C34 | 255 | 336 |
| 8.8.3          | M20–M36                    | 600 | 660 | 830 | 830<sup>6</sup> 12 | 35 | 53 | C23 | C34 | 255 | 336 |
| 9.8            | M1.6–M16                   | 650 | 720 | 900 | 900<sup>6</sup> 10 | 35 | 56 | C27 | C36 | 280 | 360 |
| 10.9           | M5–M100                    | 830 | 940 | 1040 | 1040<sup>6</sup> 9 | 35 | 59 | C33 | C39 | 327 | 382 |
| 10.9.3         | M16–M36                    | 830 | 940 | 1040 | 1040<sup>6</sup> 9 | 35 | 59 | C33 | C39 | 327 | 382 |
| 12.9<sup>E</sup> | M1.6–M100                  | 970 | 1100 | 1220 | 1220<sup>6</sup> 8 | 35 | 63 | C38 | C44 | 372 | 434 |

<sup>A</sup> Proof load and tensile strength values for full size products of each property class are given in Table 5.

<sup>B</sup> Yield strength is stress at which a permanent set of 0.2 % of gage length occurs.

<sup>C</sup> Yield point shall apply instead of yield strength at 0.2 % offset for Class 4.6 products.

<sup>D</sup> Class 5.8 applies only to bolts and screws with lengths 150 mm and shorter and to studs of all lengths.

<sup>E</sup> Caution is advised when considering the use of Class 12.9 bolts, screws, and studs. Capability of the bolt manufacturer, as well as the anticipated in-use environment, should be considered. High-strength products of Class 12.9 require rigid control of heat-treating operations and careful monitoring of as-quenched hardness, surface discontinuities, depth of partial decarburization, and freedom from carburization. Some environments may cause stress corrosion cracking of nonplated as well as electroplated products.
4.2.1 Methods other than upsetting or extrusion, or both, are permitted only by special agreement between purchaser and producer.

4.2.2 Class 4.6 may be hot or cold headed at the option of the manufacturer.

4.2.3 Classes 4.8, 5.8, 8.8, 8.8.3, 9.8, 10.9, 10.9.3, and 12.9 bolts and screws in nominal thread diameters up to M20 inclusive with lengths up to 10 times the nominal product size or 150 mm, whichever is shorter, shall be cold headed, except that they may be hot headed by special agreement with the purchaser. Larger diameters and longer lengths may be cold or hot headed at the option of the manufacturer.

4.3 Threading Practice:

4.3.1 Threads on Class 4.6 bolts and screws and on all classes of studs may be cut, rolled, or ground at the option of the manufacturer.

4.3.2 Threads on Classes 4.8, 5.8, 8.8, 8.8.3, 9.8, 10.9, 10.9.3, and 12.9 bolts and screws in nominal thread diameters up to M20 inclusive, and product lengths up to 150 mm inclusive, shall be roll threaded, except by special agreement with the purchaser. Threads of these classes on bolts and screws larger than M20 or longer than 150 mm or both, may be rolled, cut, or ground at the option of the manufacturer.

4.4 Heat Treatment:

4.4.1 Class 4.6 bolts and screws and Classes 4.6, 4.8, and 5.8 studs need not be heat treated.

4.4.2 Classes 4.8 and 5.8 bolts and screws shall be stress relieved if necessary to assure the soundness of the head to shank junction. When stress relieving is specified by the purchaser, Class 5.8 bolts and screws shall be stress relieved at a minimum stress-relief temperature of 470°C. Where higher stress-relief temperatures are necessary to relieve stresses in severely upset heads, mechanical requirements shall be agreed upon between the purchaser and producer.

4.4.3 Classes 8.8, 8.8.3, and 9.8 bolts, screws, and studs shall be heat treated by quenching in a liquid medium from above the transformation temperature and reheating to the tempering temperature given in Table 1.
### TABLE 5 Proof Load and Tensile Strength Values, kN

<table>
<thead>
<tr>
<th>Nominal Product Diameter and Thread Pitch</th>
<th>Stress Area, mm²</th>
<th>Class 4.6</th>
<th>Class 4.8</th>
<th>Class 5.8</th>
<th>Class 8.8 and 8.8.3</th>
<th>Class 9.8</th>
<th>Classes 10.9 and 10.9.3</th>
<th>Class 12.9</th>
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<tbody>
<tr>
<td></td>
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<td>Proof Load</td>
<td>Tensile Strength, min</td>
<td>Proof Load</td>
<td>Tensile Strength, min</td>
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<td><strong>Method 1</strong></td>
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<td><strong>Method 2</strong></td>
<td><strong>Method 1</strong></td>
<td><strong>Method 2</strong></td>
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<tr>
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<td>1.71</td>
<td>2.11</td>
<td>3.27</td>
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<td>2.31</td>
<td>2.85</td>
<td>4.41</td>
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<tr>
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<td>2.99</td>
<td>3.69</td>
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<tr>
<td>M5 × 0.8</td>
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<td>6.83</td>
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<tr>
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<td>11.3</td>
<td>12.4</td>
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<td>18.0</td>
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</tr>
<tr>
<td>M12 × 1.75</td>
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<td>19.0</td>
<td>20.2</td>
<td>33.7</td>
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<tr>
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<td>27.6</td>
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<tr>
<td>M16 × 2</td>
<td>157</td>
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<td>37.7</td>
<td>62.8</td>
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<tr>
<td>M20 × 2.5</td>
<td>245</td>
<td>55.1</td>
<td>58.8</td>
<td>98.0</td>
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<td>103</td>
<td>127</td>
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<td>M22 × 2.5</td>
<td>303</td>
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<td></td>
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<td>M24 × 3</td>
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<td>141</td>
<td>134</td>
<td>148</td>
<td>184</td>
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<tr>
<td>M27 × 3</td>
<td>459</td>
<td></td>
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<td>M30 × 3.5</td>
<td>561</td>
<td>126</td>
<td>135</td>
<td>224</td>
<td>337</td>
<td>370</td>
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<tr>
<td>M36 × 4</td>
<td>817</td>
<td>184</td>
<td>196</td>
<td>327</td>
<td>490</td>
<td>539</td>
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<tr>
<td>M42 × 4.5</td>
<td>1120</td>
<td>252</td>
<td>269</td>
<td>448</td>
<td>672</td>
<td>739</td>
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<tr>
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<td>331</td>
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<td>588</td>
<td>882</td>
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<tr>
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<td>2030</td>
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<td>487</td>
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<td>603</td>
<td>643</td>
<td>1070</td>
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<td>830</td>
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<td>2080</td>
<td>2280</td>
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<tr>
<td>M80 × 6</td>
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<td>977</td>
<td>1040</td>
<td>1740</td>
<td>2600</td>
<td>2860</td>
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<td>3600</td>
</tr>
<tr>
<td>M90 × 6</td>
<td>5590</td>
<td>1260</td>
<td>1340</td>
<td>2240</td>
<td>4640</td>
<td>5250</td>
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<td>5800</td>
</tr>
<tr>
<td>M100 × 6</td>
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<td>1680</td>
<td>2800</td>
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<td>6570</td>
<td>7690</td>
<td>5800</td>
</tr>
</tbody>
</table>

*Proof loads and tensile strengths are computed by multiplying the stresses given in Table 3 by the stress area of the thread.*

*Stress area, mm² = 0.7854 \( (D - 0.9382P)^2 \), where \( D \) = nominal product size, mm, and \( P \) = thread pitch, mm.*

*Proof load, Method 1, is the length measurement method as described in 3.2.3 of Test Methods F 606. Proof load, Method 2, is the yield strength method as described in 3.2.5 of Test Methods F 606.*

*For Classes 8.8 and 8.8.3 sizes M16 and smaller are not covered by Specification F 568M. Class 9.8 may be suitable for applications requiring sizes M16 and smaller after consideration of design parameters, application and service environment.*

*M22 and M27 are standard sizes for high-strength structural bolts only as covered in Specifications A 325M and A 490M.*
4.4.4 Classes 10.9, 10.9.3, and 12.9 bolts, screws, and studs shall be heat treated by quenching in oil from above the transformation temperature and reheating to the tempering temperature given in Table 1.

4.4.5 Tempering-Temperature-Audit Test—This test is a means for checking whether products were tempered at the specified temperature. The hardness (mean hardness of three hardness readings) of a bolt, screw, or stud as manufactured shall be measured. The product shall then be retempered for a minimum of 30 min per 25 mm of nominal diameter, but not less than 30 min, at a temperature 10°C less than the minimum tempering temperature specified for the property class and material in Table 1. The hardness of the retempered product shall then be measured. The difference between the hardness of the product before and after retempering shall not exceed 20 HV points.

4.5 Zinc Coatings, Hot-Dip, and Mechanically Deposited:

4.5.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc coating process, for example, hot dip, mechanically deposited, or no preference.

4.5.2 When hot-dip is specified, the fasteners shall be zinc coated by the hot-dip process in accordance with the requirements of Class C of Specification A 153.

4.5.3 When mechanically deposited is specified, the fasteners shall be zinc coated by the mechanical deposition process in accordance with the requirements of Class C of Specification A 153.

4.5.4 When no preference is specified, the supplier may furnish either a hot dip zinc coating in accordance with Specification A 153, Class C, or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. All components of mating fasteners (for example, bolts, nuts, and washers) shall be coated by the same zinc coating process, and the suppliers option is limited to one process per item with no mixed processes in a lot.

4.6 Bolts, screws, and studs of Classes 10.9 and 12.9 should not be hot-dip zinc-coated.

NOTE 1—Research conducted on bolts with properties equivalent to Class 10.9 indicated that hydrogen-stress corrosion cracking may occur in hot-dip zinc-coated fasteners of Classes 10.9 and 12.9.

5. Chemical Composition

5.1 For all classes except 8.8.3 and 10.9.3, the bolts, screws, and studs shall conform to the chemical composition specified in Table 1.

5.2 Classes 8.8.3 and 10.9.3:

5.2.1 Sizes M20 and smaller shall conform to any one of the compositions (A, B, C, D, E, or F) specified in Table 2, at the suppliers option.

5.2.2 Sizes larger than M20 shall conform to Compositions A or B specified in Table 2, at the suppliers option.

5.2.3 See Guide G 101 for methods of estimation corrosion resistance of low alloy steels.

5.3 Material analyses may be made by the purchaser from finished products representing each lot. The chemical composition thus determined shall conform to the requirements specified for the product analysis in Table 1 and Table 2.

5.4 Use of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

5.5 Chemical analyses shall be performed in accordance with Test Methods A 751.

6. Mechanical Properties

6.1 Bolts, screws, and studs shall be tested in accordance with the mechanical testing requirements for the applicable type, property class, size, and length of product as specified in Table 4, and shall meet the mechanical requirements specified for that product in Tables 3-5.

6.2 For products on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence over low readings of hardness tests.

7. Workmanship

7.1 Surface discontinuity limits shall be in accordance with Specification F 788/F 788M.

8. Number of Tests

8.1 Testing Responsibility:
8.1.1 Each lot shall be tested by the manufacturer prior to shipment in accordance with the production lot identification-control quality assurance plan in 8.2-8.5.
8.1.2 When fasteners are furnished by a source other than the manufacturer, the responsible party, as defined in 11.1 shall be responsible for ensuring that all tests have been performed and the fasteners comply with the requirements of this specification.

8.2 Purpose of Lot Inspection—The purpose of a lot inspection program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective, it is essential that secondary processors, distributors, and purchasers maintain the identification and integrity of each lot until the product is installed.

8.3 Lot Processing—All fasteners shall be processed in accordance with a lot identification-control quality assurance plan. The manufacturer, secondary processors, and distributors shall identify and maintain the integrity of each lot of fasteners from raw material selection through all processing operations and treatments to final packing and shipment. Each lot shall be assigned its own lot identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

8.4 Lot Definition:
8.4.1 Standard Lot—A lot shall be a quantity of uniquely identified fastener product of the same nominal size and length produced consecutively at the initial operations from a single mill heat of material and heat treatment lot and processed at one time by the same process in the same manner so that statistical sampling is valid. The identity of the lot and lot integrity shall be maintained throughout all subsequent operations and packaging.

8.4.2 Lots of 2000 Pieces or Fewer—Orders for 2000 pieces or fewer of the same nominal diameter but varying in length that has been processed essentially under the same conditions from the same mill heat of material and submitted for inspection at one time are considered a lot for purposes of preparing a single test report.

8.5 Number of Tests—The minimum number of tests from each lot for the tests specified below shall be as follows:

<table>
<thead>
<tr>
<th>Tests</th>
<th>Number of Tests in Accordance With</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness and Tensile Strength</td>
<td>Guide F 1470</td>
</tr>
<tr>
<td>Proof Load(^a)</td>
<td>Guide F 1470</td>
</tr>
<tr>
<td>Coating Weight/Thickness</td>
<td>The referenced coating specification(^b)</td>
</tr>
<tr>
<td>Surface Discontinuities</td>
<td>Guide F 1470</td>
</tr>
</tbody>
</table>

\(^a\) Proof load tests required only when specified on the original inquiry and purchase order. See Table 4.
\(^b\) Use Guide F 1470 if the coating specification does not specify a testing frequency.

9. Test Methods

9.1 Bolts, screws, and studs shall be tested in accordance with the methods described in Test Methods F 606M, with tension test wedge angles as specified in Table 6.

10. Inspection

10.1 If the inspection described in 10.2 is required by the purchaser, it shall be specified in the inquiry, order, or contract.
10.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy the inspector that the material is being furnished in accordance with this specification. All tests and inspection shall be made prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the work.

11. Responsibility

11.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

12. Rejection and Rehearing

12.1 Disposition of nonconforming material shall be in accordance with Guide F 1470 section titled “Disposition of Nonconforming Lots.”

13. Certification

13.1 When specified on the purchase order, the manufacturer or supplier, whichever is the responsible party in accordance with Section 11, shall furnish the purchaser a test report that includes the following:

13.1.1 Product description, grade, quantity, ASTM specification number, and issue date;
13.1.2 Heat analysis and heat number;
13.1.3 Results of the hardness and tensile tests;
13.1.4 Statement of compliance with protective coating specification;
13.1.5 Statement of compliance with the surface discontinuity requirements of Specification F 788/F 788M;
13.1.6 Statement of compliance with dimensional and thread fit specifications;
13.1.7 Report, describe, or illustrate manufacturer markings;
13.1.8 Lot number, purchase order number, and date shipped;
13.1.9 Complete mailing address of responsible party; and
13.1.10 Title and signature of the individual assigned certification responsibility by the company officers.

13.2 Failure to include all the required information on the test report shall be cause for rejection.

14. Product Marking

14.1 Bolts and Screws:

14.1.1 Bolts and screws of nominal thread diameters smaller than M5 need not be marked. Additionally, slotted and recessed screws of nominal thread diameters M5 and larger need not be marked.
14.1.2 Bolts and screws, except those covered in 14.1.1, shall be marked permanently and clearly to identify the property class and the manufacturer. The property class symbols shall be as given in Table 7. The manufacturer’s identification symbol shall be of his design.
14.1.3 For Classes 8.8.3 and 10.9.3, the manufacturer may add other distinguishing marks indicating that the bolt or screw is atmospheric corrosion resistant and of a weathering grade of steel.
14.1.4 Markings shall be located on the top of the head with the base of the property class symbols positioned toward the closest periphery of the head. Markings may be either raised or depressed at the option of the manufacturer. Alternatively, for hex head products, the markings may be indented on the side of the head with the base of the property class symbols positioned toward the bearing surface.

14.1.5 Metric bolts and screws shall not be marked with radial line symbols.

14.2 Studs:

14.2.1 Studs shall be marked permanently and clearly to identify the property class. The property class symbols and sizes to be marked shall be as given in Table 7.

14.2.2 Markings shall be located on the extreme end of the stud and may be raised or depressed at the option of the manufacturer. For studs with an interference-fit thread, the markings shall be located on the nut end.

14.2.3 When ordered by the purchaser, studs shall be marked on both ends.

15. Packaging and Package Marking

15.1 Packaging:

15.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

15.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

15.2 Package Marking:

15.2.1 Each shipping unit shall include or be plainly marked with the following information:

15.2.1.1 ASTM designation and type,
15.2.1.2 Size,
15.2.1.3 Name and brand or trademark of the manufacturer,
15.2.1.4 Number of pieces,
15.2.1.5 Purchase order number, and
15.2.1.6 Country of origin.

16. Keywords

16.1 alloy steel; bolts; carbon steel; metric; screws; steel; structural; weathering steel

APPENDIXES

(Nonmandatory Information)

X1. CONVERSION GUIDANCE

X1.1 For guidance purposes only, to assist designers and purchasers in the selection of a property class, the following conversion guidance is provided:

X1.1.1 Class 4.6 mechanical properties are approximately equivalent to those of Specification A 307, Grade A.

X1.1.2 Class 8.8 mechanical properties are approximately equivalent to those of Specification A 449, and Specification A 325, Types 1 and 2.

X1.1.3 Class 8.8.3 mechanical properties are approximately equivalent to those of Specification A 325, Type 3.

X1.1.4 Class 9.8 mechanical properties are approximately 9 % higher than those of Specification A 449.

X1.1.5 Class 10.9 mechanical properties are approximately equivalent to those of Specification A 354, Grade BD and Specification A 490, Types 1 and 2.

X1.1.6 Class 10.9.3 mechanical properties are approximately equivalent to those of Specification A 490, Type 3.

X1.1.7 Class 12.9 mechanical properties are approximately equal to those of Specification A 574.

X1.2 Class 9.8 is applicable to fasteners of nominal thread diameters M16 and smaller; Class 8.8 is applicable to fasteners larger than M16, except for Specification A 325M bolts where M16 and larger bolt diameters are Class 8.8.
X2. SIGNIFICANCE OF PROPERTY CLASS DESIGNATION

X2.1 Property classes are designated by numbers where increasing numbers generally represent increasing tensile strengths. The designation symbol has the following significance:

X2.1.1 The one or two numerals preceding the first decimal point approximates $\frac{1}{100}$ of the minimum tensile strength in MPa.

X2.1.2 The numeral following the first decimal point approximates $\frac{1}{10}$ of the ratio, expressed as a percentage, between minimum yield stress and minimum tensile strength.

X2.1.3 The numeral 3, following the second decimal point, is an indicator that the material has atmospheric corrosion resistance and weathering characteristics comparable to steels covered in Specification A 588/A 588M.

SUMMARY OF CHANGES

This section identifies the location of selected changes to this standard that have been incorporated since the –98 issue. For the convenience of the user, Committee F16 has highlighted those changes that may impact the use of this standard. This section may also include descriptions of the changes or reasons for the changes, or both.

(1) Deleted 3.2, “Government Provisioning,” because it is no longer applicable.

(2) Revised section 8, “Number of Tests,” as follows:
   Required lot control,
   Referenced Guide F 1470 for mechanical property and surface discontinuity testing,
   Referenced the coating specification for coating test frequency, and

   Added paragraph 8.4.2 providing for a single test report for lots of 2000 pieces or fewer varying only in length.

(3) Added section 12, “Rejection and Rehearing.”

(4) Added section 13, “Certification,” on a when-specified basis.
Standard Terminology of Collated and Cohered Fasteners and Their Application Tools

INTRODUCTION

The terms included in these definitions are listed in alphabetical order to facilitate quick reference. They are intended to apply to collated and cohered nails, staples, and pins driven by strike, pneumatic, electric, manual, and spring tools. Omitted from consideration are terms relating to the testing and the performance of fasteners, that is, their drivability, withdrawal resistance, pull-through resistance, lateral load transmission, creep, protrusion resistance, splitting, and methods of use, such as face, toe, side, and end-nailing, spacing, loading conditions, etc. Reference is made to ASTM Terminology F 547, Terminology of Nails for Use with Wood and Wood-Base Materials, for terms that are applicable to related fasteners that may or may not be collated or cohered.

Common acceptance and usage are the basis for most of the definitions listed. In some instances, this common usage results in more than one definition for a given term. In other cases, registered trademarks have become generic in nature; hence, are included among the terms listed.

Any such listing cannot be complete. As additional terms are referred to the Society’s attention, they will be considered for inclusion in this standard.

This listing of definitions of terms is in agreement so far as feasible with and supplementary to Terminology F 547.

The definitions are listed under the following headings:

Collated and Cohered Fasteners
Tools for Driving Collated and Cohered Fasteners

Collated and Cohered Fasteners

bevel point—point sheared obliquely to staple-leg axis, with beveled face across staple-leg end; used to produce an outward clinch or to provide additional penetration, or both, in thin stapling member (see Fig. 1(A)).

blind clinch—clinch between the layers of corrugated boards, usually buried with wide-crown retractable anvil tools.

bookbinder’s wire—wire used in stitchers to fasten paper; measured according to AWG sizes.

box stay wire—wire used in stitchers for assembly of containers; with dimensions measured in thousandths of inches.

breakaway staple—staple with its crown designed to break off if removal is attempted; used to discourage pilfering and shop-lifting.

by-pass clinch—clinch with legs paralleling and adjacent to each other.

calendar staple—staple formed to provide a hanger for use with calendars or booklets.

chisel point—point with two symmetrically beveled planes forming “V” at end of staple leg, resulting in straight penetration (see Fig. 1(B)). (See cross-cut chisel point.)

clinch—protruding point end turned over or flattened when driven or driven against clinching plate.

clinch point—point designed to facilitate clinching when driven against clinching plate. (See step point.)

clip—See strip.

clipped head—misnomer for D head. (See notched head.)

coated fastener—a fastener with appropriate material applied to its surface to increase the fastener-withdrawal resistance.

cohered—assembled in strip, coil, or other predetermined form as defined in Terminology F 547.

coiled—assembled in coil form.

collated—assembled in strip or other predetermined form.

cross-cut chisel point—chisel point with beveled point faces parallel to staple-crown axis (see Fig. 1(C)). (See right-angle chisel point.)
crown—staple end opposite staple point, connecting both
staple legs and providing bearing area.
crown width—overall width of staple including both staple legs.
D head—nail head with semi-circular rim and head segment omitted during heading, with omitted segment reaching from rim to shank projection, to allow tight collating of nails in strip form.
divergent point—See divergent bevel point.
divergent bevel point—points sheared obliquely to staple-leg axis, with beveled face in opposite direction on each leg, across thick leg side leading from lower to upper thick face; designed to lead staple legs into opposite directions perpendicular to staple plane during driving (see Fig. 1(D)).
divergent chisel point—chisel point with beveled point faces at angle to staple crown in plane perpendicular to staple crown axis; designed to lead staple legs into opposite directions perpendicular to staple plane during driving (see Fig. 1(E)).
flat clinch—clinch formed by folding staple legs parallel to crown with movable clincher.
flared—staple legs spread into outward opposite directions 90° with crown plane.
flat crown—straight staple crown in contrast to rounded, formed, or offset staple crown.
formed crown—staple crown formed during driving, for example, for carding or fastening wire.
high crown—staple crown with inverted “V” wire cross-section prior to staple driving; designed to provide rigidity during driving and flattened when fully driven. (see “V” Crown.)
hog ring, hog-ring staple—open-ended, rounded, ring, or
rectangular “U”-formed staple; used for encircling applications, that is, for attaching materials to rounded or rectangular base material by closing or wrapping hog ring around base material.

**hybar wire**—flat wire normally used in box stitching. Specifically:

<table>
<thead>
<tr>
<th>Gage No.</th>
<th>Cross-Sectional Dimensions, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>0.060 by 0.017 (1.52 by 0.43)</td>
</tr>
<tr>
<td>00</td>
<td>0.060 by 0.018 (1.52 by 0.46)</td>
</tr>
<tr>
<td>0</td>
<td>0.060 by 0.019 (1.52 by 0.48)</td>
</tr>
<tr>
<td>1</td>
<td>0.060 by 0.020 (1.52 by 0.51)</td>
</tr>
<tr>
<td>2</td>
<td>0.060 by 0.024 (1.52 by 0.61)</td>
</tr>
<tr>
<td>3</td>
<td>0.060 by 0.028 (1.52 by 0.71)</td>
</tr>
</tbody>
</table>

**incomplete head**—nail head with semi-circular rim and portion of head omitted during heading, to allow tight collating of nails in strip form. (See **D head, notched head**.)

**in-line clinch**—flat clinch with both staple legs in straight alignment.

**inside bevel point**—bevel point with its beveled face on staple inside; used to produce an outward clinch or to provide additional penetration in the base material, or both (see Fig. 1(8)).

**leg**—staple part connecting staple crown with staple point; driven through and into or through materials being fastened.

**leg thickness**—maximum dimension of staple-leg cross section measured parallel to staple-crown axis.

**leg width**—maximum dimension of staple-leg cross section measured perpendicular to staple-crown axis.

**lock stitch**—a double stitch used at beginning and end of manufacturer’s seam on corrugated boxes.

**manufacturer’s seam**—joint produced by corrugated box manufacturer during container fabrication.

**medium crown**—staple crown usually larger than 5/16 in. (8 mm) in width.

**narrow crown**—staple crown usually 5/16 in. (8 mm) in width or smaller.

**notched head**—nail head with semi-circular rim and “V”-notch, having rounded “V” corners, wide notch part at rim, and narrow notch part at nail-shank projection, formed during heading, to allow tight collating of nails in strip form.

**outside bevel point**—bevel point with its beveled face on staple outside (see Fig. 1(F)).

**outside bevel divergent point**—staple point with two-plane beveled face on staple outside and along thick leg side; designed to lead staple legs into opposite directions and to result at the same time in their crossing during driving (see Fig. 1(H)).

**outward clinch**—clinch with both staple legs flared outwardly during driving.

**partially preformed**—not fully formed prior to driving.

**preformed**—formed prior to driving.

**rack**—longitudinal offset between adjacent fasteners within strip of collated fasteners.

**racked fastener**—fastener offset in strip.

**ribbon wire**—box stay wire of nominal 0.103 in. (2.62 mm) in width.

**right-angle chisel point**—chisel point with beveled point faces parallel to staple-crown axis (see Fig. 1(J)). (See **cross-cut chisel point**.)

**rolled clinch**—clinch formed by solid clincher against which staple point is driven; obtained normally with desk stapler.

**round or rounded crown**—curved staple crown used in wiring, carding, and encircling operations; also, in spring-up applications in furniture manufacturing.

**saddle stapling**—pamphlet or book stapling on a “V”-shaped table, which permits placement of staple in center fold.

**saddle stitching**—Similar to saddle stapling; however, accomplished with wire stitcher.

**spear point**—symmetrical point with four bevel faces meeting at point center (see Fig. 1(J)).

**spring-clip staple**—staple for fastening flat metal clip holding undulated upholstery spring. Also, staple used to attach coiled springs to frame in bedding manufacture where staple serves as clip.

**spring crown**—hip crown; designed to flatten during driving in order to provide optimum lateral guidance in driving channel of stapler. (See **high crown; “V” crown**.)

**square point**—point sheared perpendicular to staple-leg axis to form a pointless staple-leg end; known as blunt point (see Fig. 1(K)).

**standard staple**—staple with nominal 1/2 in. (13 mm)-wide crown, 1/4 in. (6 mm)-long legs, made of 0.019 in. (0.48 mm) wire, commonly used in desk-type staplers.

**staple**—“U”-shaped wire fastener usually with two same-size pointed or pointless legs connected by crown located opposite staple-point ends; designed to be driven by strike, pneumatic, electric, manual or spring tools through or through and into layers of penetrable material and to hold two or more pieces together.

**staple length**—distance from top of staple crown to tip of staple point (see Fig. 1(F)). Also referred to as leg length. In contrast, length of bulk staple, driven by hand-hammer, is measured from bottom of staple crown to tip of staple point.

**staple point**—See **bevel point, chisel point, clinch point, cross-cut chisel point, divergent point, inside bevel point, outside bevel point, outside bevel divergent point, right-angle chisel point, spear point, step point**.

**staple spacing**—dimension used to describe the relative location of staple or staples in workpiece; often, the dimension to center or center-to-center of staple.

**step point**—notched point with step faces perpendicular to staple crown; designed to facilitate self-clinching of staple legs when driven against clinching plate (see Fig. 1(L)).

**stick**—See **strip**.

**stitch**—staple cut and formed from wire immediately prior to driving by same machine.

**strip**—staples, nails, or pins collated and cohered to facilitate automatic driving with appropriate tool.

**tie stitch**—See **lock stitch**.

**tube terminal staple**—staple designed for use as a wiring terminal in electronic assembly.

**undulated staple**—staple with curves in crown for better driving stability.

**“V”-crown**—staple crown with inverted “V” cross section on staple; used in spring-up work in furniture and bedding.

**wide crown**—staple crown usually larger than 11/16 in. (17 mm) in width.
TOOLS FOR DRIVING COLLATED AND COHERED FASTENERS

anvil—tool arm against which staple legs are driven to form clinch.
arm—cantilever part of tool to hold the clinching mechanism, permitting placement of fastener away from edges of the work.
automatic trip—machine-activated tool mechanism providing continuous cycling while trip is in contact with the work.
blade clincher—thin clinching arm; usually designed for insertion between layers of corrugated boards.
bottom trip—tool activation by tool nose touching the work, while at the same time activating trigger trip.
button clincher—circular clincher. “C” blade—blade clincher resembling the letter “C”; designed to fasten partially overlapping container panels.
clincher—part of tool that folds fastener legs to form clinch.
clinching plate—(See anvil.) Also, hardened flat metal plate; used in clinching nails and staples designed for clinching.
coil-fed tool—tool utilizing a coil of collated fasteners or a coil or wire.
contact trip—See bottom trip.
core—See rail.
door—combination nose and closure for nose-loading stapler.
driver—tool component that pushes fastener from the driving chamber of the tool into the members being assembled.
feeder shoe—See pusher.
follower—See pusher.
forked blade clincher—special clincher (anvil) for hooking plastic bags to facilitate placement of encircling staple.
grooved guide body—formed guiding device used for placing staple over work as in carding or wiring.
guide body—tool component that aligns and supports staple during driving.
lip—overhang of tool nose when magazine rests flush with work surface.
long magazine—magazine providing space for more than regular capacity of a particular tool style.
magazine—mechanism for storing and feeding fasteners.
mattress blade—special clinching blade for fastening sisal pads in bedding plants, permitting stapling inside edging wire.
movable by-pass clincher—clinching mechanism for forming a by-pass clinch.
movable in-line clincher—clinching mechanism for forming an in-line clinch.
nose—guide-body area where fastener is driven from tool.
nose extension—See lip.
overhang—See lip.
plier—portable stapler with attached clincher for placing staples away from edges of work.
pointed blade—See pointed clincher.
pointed clincher—blade clincher with sharp point to facilitate piercing of corrugated board.
post—post holding clincher to facilitate assembly of container bottoms.
pusher—tool mechanism for forcing fastener into driving channel.
rail—magazine component required for alignment of fastener and directing it into driving channel.
remote fire tool—remotely controlled tool.
retractable anvil—curved clincher used in stapling from outside of container.
safety mechanism—a device intended to prevent accidental actuation of tool.
sealing blade—See blade clincher.
sidestrike—activation of stapling head resulting from forcing container resting on table against head.
sisal plier—See plier; mattress blade.
slanted magazine—a magazine attached at an angle to tool; used for storing clips of slanted nails or staples.
solid clincher—non-moving clincher.
stick-fed tool—See strip-fed tool.
strike tacker—stapler activated by striking it with hand or mallet.
stitcher—machine that cuts, forms, and drives wire stitches.
stitching wire—See box stay wire.
strip-fed tool—tool using staples or nails that are collated and cohered in strip form.
supporter—cam mechanism, especially spring-loaded; designed to provide crown and lateral guidance for staple in driving channel of stapler.
sword-point anvil—See pointed clincher.
stacker—electric, manual, or pneumatic tool for driving light-wire staples without clinching.
throat depth—distance at which a tool may place fastener from edge of the work.
tool—machine for driving fasteners.
touch trip—See bottom trip.
track—See rail.
trigger trip—tool activation by trigger operation in conjunction with bottom trip activation.
walking stick—long arm attached to tool allowing operator to use it without bending over.
Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs

1. Scope

1.1 This specification covers the requirements for stainless steel bolts, hex cap screws, and studs 0.25 to 1.50 in., inclusive, in nominal diameter in a number of alloys in common use and intended for service applications requiring general corrosion resistance.

1.2 Seven groups of stainless steel alloys are covered, including twelve austenitic, two ferritic, four martensitic, and one precipitation hardening.

<table>
<thead>
<tr>
<th>Group</th>
<th>Alloys</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>304, 305, 384, 304 L, 18-9LW, 302HQ</td>
<td>(CW) cold worked</td>
</tr>
<tr>
<td>2</td>
<td>316, 316 L</td>
<td>(CW) cold worked</td>
</tr>
<tr>
<td>3</td>
<td>321, 347</td>
<td>(CW) cold worked</td>
</tr>
<tr>
<td>4</td>
<td>430F</td>
<td>(CW) cold worked</td>
</tr>
<tr>
<td>5</td>
<td>410F</td>
<td>(H) hardened and tempered</td>
</tr>
<tr>
<td>6</td>
<td>431</td>
<td>(H) hardened and tempered</td>
</tr>
<tr>
<td>7</td>
<td>630</td>
<td>(AH) age hardened</td>
</tr>
</tbody>
</table>

A Unless otherwise specified on the inquiry and order, the choice of an alloy from within a group shall be at the discretion of the fastener manufacturer (see 6.1).
B See 4.2 for options.
C Sizes 0.75 in. and larger may be hot worked and solution annealed.
D When approved by the purchaser, Alloy 430F may be furnished.
E When approved by the purchaser, Alloys 410 or 416Se may be furnished.

1.3 Supplementary requirements of an optional nature are provided, applicable only when agreed upon between the manufacturer and the purchaser at the time of the inquiry and order.

1.4 Suitable nuts for use with bolts, hex cap screws, and studs included in this specification are covered by Specification F 594. Unless otherwise specified, all nuts used on these fasteners shall conform to the requirements of Specification F 594, shall be of the same alloy group, and shall have a specified minimum proof stress equal to or greater than the specified minimum full-size tensile strength of the externally threaded fastener.

2. Referenced Documents

2.1 ASTM Standards:
A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
A 276 Specification for Stainless Steel Bars and Shapes
A 342/A 342M Test Methods for Permeability of Feebly Magnetic Materials
A 380 Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
A 484/A 484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings
A 493 Specification for Stainless Steel Wire and Wire Rods for Cold Heading and Cold Forging
A 555/A 555M Specification for General Requirements for Stainless Steel Wire and Wire Rods
A 564/A 564M Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes
A 582/A 582M Specification for Free-Machining Stainless Steel Bars
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A 967 Specification for Chemical Passivation Treatments for Stainless Steel Parts
D 3951 Practice for Commercial Packaging
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
F 594 Specification for Stainless Steel Nuts
F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

2.2 ASME Standards:
B1.1 Unified Inch Screw Threads

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1 This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.04 on Nonferrous Fasteners.


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2 Annual Book of ASTM Standards, Vol 01.03.
3 Annual Book of ASTM Standards, Vol 03.04
6 Annual Book of ASTM Standards, Vol 01.08.
3. Ordering Information

3.1 Orders for bolts, hex cap screws, and studs under this specification shall include the following:
   3.1.1 Quantity (number of pieces of each item and size),
   3.1.2 Name of item (bolt, hex cap screw, stud, etc.),
   3.1.3 Size (nominal diameter, threads per inch, length; see Section 9),
   3.1.4 Alloy group number (see 6.1), and
   3.1.5 Condition (see 4.2).

3.2 Orders for bolts, hex cap screws, and studs under this specification may include the following optional requirements:
   3.2.1 Forming (see 4.1.2),
   3.2.2 Rolled or cut threads (see 4.1.3),
   3.2.3 Composition (see 6.2),
   3.2.4 Corrosion Resistance (see 8.1),
   3.2.5 Finish (see 10.3),
   3.2.6 Rejection (see 16.1), and
   3.2.7 Test report (see 17.2).

3.2.8 Supplementary requirements, if any, to be specified on the order (see S1 through S8), and
3.2.9 ASTM specification and year of issue. When year of issue is not specified, fasteners shall be furnished to the latest issue.

Note 1—Example 10 000 pieces, Hex Cap Screw, 0.250 in. × 20 × 3.00 in., Alloy Group 1, Condition CW, Furnish Test Report, Supplementary Requirement S3.

4. Manufacture

4.1 Manufacture:

4.1.1 Specifications A 276, A 493, A 564/A 564M, and A 582/A 582M are noted for information only as suitable sources of material for the manufacture of bolts, hex cap screws, and studs to this specification.

4.1.2 Forming—Unless otherwise specified, the fasteners shall be cold formed, hot formed, or machined from suitable material at the option of the manufacturer.

4.1.3 Threads—Unless otherwise specified, the threads shall be rolled or cut at the option of the manufacturer.

4.2 Condition—The fasteners shall be furnished in the following conditions, unless specified to be furnished in one of the optional conditions:

<table>
<thead>
<tr>
<th>Alloy Group</th>
<th>Condition Furnished Unless Otherwise Specified</th>
<th>Optional Conditions (must be specified)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 2, 3</td>
<td>CW</td>
<td>AF, A, SH</td>
</tr>
<tr>
<td>4</td>
<td>CW</td>
<td>A</td>
</tr>
<tr>
<td>5</td>
<td>H</td>
<td>HT</td>
</tr>
<tr>
<td>6</td>
<td>H</td>
<td>HT</td>
</tr>
<tr>
<td>7</td>
<td>AH</td>
<td>none</td>
</tr>
</tbody>
</table>

A—Machined from annealed or solution-annealed stock thus retaining the properties of the original material; or hot-formed annealed or solution annealed.

AF—Heeded and rolled from annealed stock and then reannealed.

AH—Solution-annealed and age-hardened after forming.

CW—Heeded and rolled from annealed stock thus acquiring a degree of cold work. Sizes 0.75 in. and larger may be hot-worked and solution-annealed.

H—Hardened and tempered at 1050°F (565°C) minimum.

HT—Hardened and tempered at 525°F (274°C) minimum.

5. Heat Treatment

5.1 Alloy Groups 1, 2, and 3 (Austenitic Alloys 303, 303Se, 304, 304 L, 305, 316, 316 L, 321, 347, 384, XM1, 18-9LW, and 302HQ):

5.1.1 Condition A—When Condition A is specified, the austenitic alloys shall be heated to 1900 ± 50°F (1038 ± 28°C), at which time the chromium carbide will go into the solution, be held for a sufficient time, and then be cooled at a rate sufficient to prevent precipitation of the carbide and to provide the specified properties.

5.1.2 Condition CW—When Condition CW is specified, the austenitic alloys shall be annealed in accordance with 5.1.1, generally by the raw material manufacturer and then cold worked to develop the specified properties.

5.1.3 Condition AF—When Condition AF is specified, the austenitic alloys shall be annealed in accordance with 5.1.1 after all cold working (including heading and threading) has been completed.

5.2 Alloy Group 4 (Ferritic Alloys 430 and 430F):

5.2.1 Condition A—The ferrite alloys shall be heated to a temperature of 1450 ± 50°F (788 ± 28°C), held for an appropriate time, and then air cooled to provide the specified properties.

5.2.2 Condition CW—When Condition CW is specified, the ferrite alloys shall be annealed in accordance with 5.2.1 after all cold working (including heading and threading) has been completed.

5.3 Alloy Group 5 (Martensitic Alloys 410, 416, and 416Se):

5.3.1 Condition H—When Condition H is specified, the Martensitic Alloys 410, 416, and 416Se shall be hardened and tempered by heating to 1850 ± 50°F (1010 ± 28°C) sufficient for austenitization, held for at least ½ h and rapid air- or oil-quenched, and then reheating to 1050°F (565°C) minimum for at least 1 h and air cooled to provide the specified properties.

5.3.2 Condition HT—When Condition HT is specified, the Martensitic Alloys 410, 416, and 416Se shall be hardened and tempered by heating to 1850 ± 50°F (1010 ± 28°C) sufficient for austenitization, held for at least ½ h and rapid air- or oil-quenched, and then reheating to 525°F (274°C) minimum for at least 1 h and air cooled to provide the specified properties.

5.4 Alloy Group 6 (Martensitic Alloy 431):

5.4.1 Conditions H and HT—Martensitic Alloy 431 shall be hardened and tempered in accordance with 5.3.1 and 5.3.2 as applicable.

5.5 Alloy Group 7 (Precipitation Hardening Alloy 630):

5.5.1 Condition A—Precipitation Hardening Alloy 630 shall be solution annealed and aged by heating to 1900 ± 25°F (1038 ± 14°C) for at least ½ h and rapid air- or oil-quenched to 80°F (27°C) maximum, then reheating to a temperature of
1150 ± 15°F (621 ± 8°C) for 4 h and air cooled to provide the specified properties.

6. Chemical Composition

6.1 Alloy Groups—It is the intent of this specification that fasteners shall be ordered by alloy group numbers, which include alloys considered to be chemically equivalent for general purpose use. The alloy groupings are shown as follows. The purchaser has the option of ordering a specific alloy, in stead of an alloy group number, as permitted in 6.2.2.

<table>
<thead>
<tr>
<th>Alloy Group</th>
<th>Alloys</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>304, 304 L, 305, 384, 18-9LW, 302HQ&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>316, 316 L</td>
</tr>
<tr>
<td>3</td>
<td>321, 347</td>
</tr>
<tr>
<td>4</td>
<td>430&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>410&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>6</td>
<td>431</td>
</tr>
<tr>
<td>7</td>
<td>630</td>
</tr>
</tbody>
</table>

<sup>a</sup> When approved by the purchaser, Alloys 303, 303Se, or XM1 may be furnished.

<sup>b</sup> When approved by the purchaser, Alloy 430F may be furnished.

<sup>c</sup> When approved by the purchaser, Alloys 416 or 416Se may be furnished.

6.2 Chemical Composition Limits:

6.2.1 Ordering by Alloy Group—Unless otherwise specified on the inquiry and order (see Supplementary Requirement S4), the choice of an alloy from within a group shall be at the discretion of the fastener manufacturer as required by his method of fastener fabrication and material availability. The specific alloy used by the fastener manufacturer shall be clearly identified on any certification required by the order and shall have a chemical composition conforming to the requirements of Table 1 for the specific alloy.

6.2.2 Ordering by Specific Alloy—When ordered by a specific alloy number, the fasteners shall conform to the chemical composition limits of Table 1 for the specific alloy.

6.3 Product Analysis:

6.3.1 When performed, product analysis to determine chemical composition shall be performed on at least one fully manufactured finished fastener representing each lot. The chemical composition thus determined shall conform to the requirements of Table 1 for the specified alloy or alloy group as appropriate, subject to the Product Analysis Tolerance in Specifications A 484/A 484M and A 555/A 555M.

6.3.2 In the event of discrepancy, a referee chemical analysis of samples from each lot shall be made in accordance with 14.1.

7. Mechanical Properties

7.1 The finished fasteners shall meet the applicable mechanical property and test requirements of Table 2 and Table 3 as appropriate for the specified alloy group and condition and shall be tested for conformance to the mechanical property requirements as specified herein.

7.2 Fasteners having a nominal thread diameter-length combination as follows:

<table>
<thead>
<tr>
<th>Thread Diameter, in.</th>
<th>Thread Length, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75 or less</td>
<td>2.25 D or longer</td>
</tr>
<tr>
<td>Over 0.75</td>
<td>3 D or longer</td>
</tr>
</tbody>
</table>

and a breaking load of 120 000 lbf (535 kN) or less shall be tested full size and shall meet the full-size tensile (minimum and maximum) and yield strength requirements in Table 2 for the specified alloy.

7.3 Fasteners having a nominal thread diameter-length combination in accordance with 7.2 and a breaking load exceeding

---

**TABLE 1 Chemical Requirements**

<table>
<thead>
<tr>
<th>Alloy Group Designation</th>
<th>Alloy</th>
<th>Composition, % maximum except as shown</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Carbon</td>
</tr>
<tr>
<td><strong>Austenitic Alloys</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>S30300</td>
<td>303</td>
</tr>
<tr>
<td>2</td>
<td>S30323</td>
<td>303Se</td>
</tr>
<tr>
<td>3</td>
<td>S30400</td>
<td>304</td>
</tr>
<tr>
<td>4</td>
<td>S30403</td>
<td>304 L</td>
</tr>
<tr>
<td>5</td>
<td>S30500</td>
<td>305</td>
</tr>
<tr>
<td>6</td>
<td>S38400</td>
<td>384</td>
</tr>
<tr>
<td>7</td>
<td>S20300</td>
<td>XM1</td>
</tr>
<tr>
<td>8</td>
<td>S30430</td>
<td>18-9LW</td>
</tr>
<tr>
<td>9</td>
<td>S30432</td>
<td>302HQ</td>
</tr>
<tr>
<td>10</td>
<td>S31600</td>
<td>316</td>
</tr>
<tr>
<td>11</td>
<td>S31603</td>
<td>316 L</td>
</tr>
<tr>
<td>12</td>
<td>S32100</td>
<td>321</td>
</tr>
<tr>
<td>13</td>
<td>S34700</td>
<td>347</td>
</tr>
<tr>
<td><strong>Ferritic Alloys</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>S43000</td>
<td>430</td>
</tr>
<tr>
<td>5</td>
<td>S43020</td>
<td>430F</td>
</tr>
<tr>
<td><strong>Martensitic Alloys</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>S41000</td>
<td>410</td>
</tr>
<tr>
<td>6</td>
<td>S41600</td>
<td>416</td>
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<tr>
<td>7</td>
<td>S41623</td>
<td>416Se</td>
</tr>
<tr>
<td>8</td>
<td>S43100</td>
<td>431</td>
</tr>
<tr>
<td><strong>Precipitation Hardening Alloys</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>S17400</td>
<td>630</td>
</tr>
</tbody>
</table>

<sup>a</sup> At manufacturer's option, determined only when intentionally added.
120,000 lbf (535 kN) shall be tested full-size and shall meet the full-size tensile (minimum and maximum) and yield strength properties in Table 2. When equipment of sufficient capacity for such tests is not available, or if excessive length of the fasteners makes full-size testing impractical, use of standard or round specimens that meet the "machined specimen test tensile properties" in Table 2 is permitted. In the event of discrepancy or dispute between test results obtained from full-size finished fasteners and standard or round specimens, the referee method shall be tests performed on full-size finished fasteners.

7.4 Fasteners that are too short (lengths less than that specified in 7.2 (see Test Methods F 606 and Table 4); have insufficient threads for tension; or have drilled or undersized heads, drilled or reduced bodies, and so forth, that are weaker

| Table 2 Mechanical Property Requirements | \( F_{593} \)
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless Alloy Group</td>
<td>Condition</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>( 1 ) (303, 304, 304 L, 305, 384, XM1, 18-9LW, 302HQ, 303Se)</td>
<td>AF</td>
</tr>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>CW1</td>
</tr>
<tr>
<td></td>
<td>CW2</td>
</tr>
<tr>
<td></td>
<td>SH1</td>
</tr>
<tr>
<td></td>
<td>SH2</td>
</tr>
<tr>
<td></td>
<td>SH3</td>
</tr>
<tr>
<td></td>
<td>SH4</td>
</tr>
<tr>
<td>( 2 ) (316, 316L)</td>
<td>AF</td>
</tr>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>CW1</td>
</tr>
<tr>
<td></td>
<td>CW2</td>
</tr>
<tr>
<td></td>
<td>SH1</td>
</tr>
<tr>
<td></td>
<td>SH2</td>
</tr>
<tr>
<td></td>
<td>SH3</td>
</tr>
<tr>
<td></td>
<td>SH4</td>
</tr>
<tr>
<td>( 3 ) (321, 347)</td>
<td>AF</td>
</tr>
<tr>
<td></td>
<td>A</td>
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<tr>
<td></td>
<td>CW1</td>
</tr>
<tr>
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<td>CW2</td>
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<tr>
<td></td>
<td>SH1</td>
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<td></td>
<td>SH2</td>
</tr>
<tr>
<td></td>
<td>SH3</td>
</tr>
<tr>
<td></td>
<td>SH4</td>
</tr>
<tr>
<td>( 4 ) (340, 340F)</td>
<td>AF</td>
</tr>
<tr>
<td></td>
<td>A</td>
</tr>
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<td></td>
<td>CW1</td>
</tr>
<tr>
<td></td>
<td>CW2</td>
</tr>
<tr>
<td>( 5 ) (410, 416, 416Se)</td>
<td>H</td>
</tr>
<tr>
<td></td>
<td>HT</td>
</tr>
<tr>
<td>( 6 ) (431)</td>
<td>H</td>
</tr>
<tr>
<td></td>
<td>HT</td>
</tr>
<tr>
<td>( 7 ) (630)</td>
<td>AH</td>
</tr>
</tbody>
</table>

\(^{a}\) Minimum values except where shown as maximum or as a range.

\(^{b}\) Legend of conditions:
A—Machined from annealed or solution-annealed stock thus retaining the properties of the original material, or hot-formed and solution-annealed.
AF—Headed and rolled from annealed stock and then reannealed.
AH—Solution annealed and age-hardened after forming.
CW—Headed and rolled from annealed stock thus acquiring a degree of cold work; sizes 0.75 in. and larger may be hot worked and solution-annealed.
H—Hardened and tempered at 1050°F (565°C) minimum.
HT—Hardened and tempered at 525°F (274°C) minimum.
SH—Machined from strain hardened stock or cold-worked to develop the specified properties.

\(^{c}\) The yield and tensile strength values for full-size products shall be computed by dividing the yield and maximum tensile load values by the stress area for the product size and thread series determined in accordance with Test Methods F 606 (see Table 4).

\(^{d}\) Yield strength is the stress at which an offset of 0.2 % gage length occurs.

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NOTICE: This standard has either been superceded and replaced by a new version or discontinued. Contact ASTM International (www.astm.org) for the latest information.
than the thread section, shall not be subject to tension tests but shall conform to the hardness (minimum and maximum) requirements of Table 2.

8. Corrosion Resistance

8.1 Carbide Precipitation:

8.1.1 Rod, bar, and wire in the austenitic Alloy Groups 1, 2, and 3, except the free-machining grades, 303 and 303Se, used to make fasteners in accordance with this specification shall be capable of passing the test for susceptibility to intergranular corrosion as specified in Practice E of Practices A 262.

8.1.2 As stated in Practice A 262, samples may be subjected to the faster and more severe screening test in accordance with Practice A. Failing Practice A, specimens shall be tested in accordance with Practice E and be considered satisfactory if passing Practice E.

9. Dimensions

9.1 Bolts and Hex Cap Screws:

9.1.1 Unless otherwise specified, the dimensions shall be in accordance with the requirements of ASME B18.2.1 for hex cap screws (finished hex bolts).

9.1.2 When specified, the dimensions of bolts shall be in accordance with the requirements of ASME B18.2.1 (type as specified), or such other dimensions shall be specified.

9.2 Studs—Dimensions of studs including double-end clamping and double-end interference shall be as specified by the purchaser.

9.3 Threads—Unless otherwise specified, the bolts, cap screws, and studs shall have Class 2A threads in accordance with ASME B1.1.
9.4 Points—Unless otherwise specified, the points shall be flat and chamfered or rounded, at the option of the manufacturer.

10. Workmanship and Finish

10.1 Workmanship—The fasteners shall have a workman-like finish, free of injurious burrs, seams, laps, irregular surfaces, and other defects affecting serviceability.

10.2 Cleaning and Descaling—The fasteners shall be descaled or cleaned, or both, in accordance with Specification A 380.

10.3 Protective Finishes—Unless otherwise specified, the fasteners shall be furnished without an additive chemical or metallic finish.

11. Sampling

11.1 A lot, for the purposes of selecting test specimens, shall consist of not more than 100,000 pieces offered for inspection at one time having the following common characteristics:

11.1.1 One type of item (that is, bolts, hex cap screws, studs, etc.),
11.1.2 Same alloy and condition,
11.1.3 One nominal diameter and thread series,
11.1.4 One nominal length,
11.1.5 Produced from one heat of material, and
11.1.6 Heat treated under the same conditions as to time and temperature.

12. Number of Tests and Retests

12.1 Number of Tests:

12.1.1 Mechanical Tests—The mechanical requirements of this specification shall be met in continuous mass production for stock. The manufacturer shall make sample inspections as specified below to ensure that the product conforms to the specified requirements. When tests of individual shipments are required, Supplementary Requirement S1 must be specified in the inquiry and order.

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Tests</th>
<th>Acceptance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 50</td>
<td>2</td>
<td>Acceptance Number</td>
</tr>
<tr>
<td>51 to 500</td>
<td>3</td>
<td>Acceptance Number</td>
</tr>
<tr>
<td>501 to 35,000</td>
<td>5</td>
<td>Acceptance Number</td>
</tr>
<tr>
<td>35,001 to 100,000</td>
<td>8</td>
<td>Acceptance Number</td>
</tr>
</tbody>
</table>

12.1.2 Corrosion Resistance Tests:

12.1.2.1 Unless otherwise specified, inspection for corrosion resistance shall be in accordance with the manufacturer’s standard quality control practices. No specific method of inspection is required, but the fasteners shall be produced from suitable raw material and manufactured by properly controlled practices to maintain resistance to corrosion. When corrosion tests are required, Supplementary Requirement S7 must be specified in the inquiry and order, except as noted in 12.1.2.2.

12.1.2.2 Products that have been hot worked shall be solution annealed and tested to determine freedom from precipitated carbides. Not less than one corrosion test shall be made from each lot. Corrosion tests shall be performed in accordance with Practice A 262, Practices A or E as applicable.

12.2 Retests:

12.2.1 When tested in accordance with the required sampling plan, a lot shall be subject to rejection if any of the test specimens fail to meet the applicable test requirements.

12.2.2 If the failure of a test specimen is due to improper preparation of the specimen or to incorrect testing technique, the specimen shall be discarded and another specimen substituted.

13. Significance of Numerical Limits

13.1 For the purposes of determining compliance with the specified limits for properties listed in this specification, an observed value or calculated value shall be rounded in accordance with Practice E 29.

14. Test Specimens

14.1 Chemical Tests—When required, samples for chemical analysis shall be taken by drilling, sawing, milling, turning, clipping, or other such methods capable of producing representative samples.

14.2 Mechanical Tests:

14.2.1 Specimens shall be full size or machined in accordance with 7.2 through 7.4. Machined specimens, when required, shall be machined from the fastener in accordance with Test Methods F 606.

14.2.2 The hardness shall be determined on the finished fastener in accordance with Test Methods F 606.

14.3 Corrosion Resistance—Test specimens shall be prepared in accordance with Practices A 262.

15. Test Methods

15.1 Chemical Analysis—The chemical composition shall be determined in accordance with Test Methods A 751.

15.1.1 The fastener manufacturer may accept the chemical analysis of each heat of raw material purchased and reported on the raw material certification furnished by the raw material producer. The fastener manufacturer is not required to do any further chemical analysis testing provided that precise heat traceability has been maintained throughout the manufacturing process on each lot of fasteners produced and delivered.

15.2 Mechanical Tests:

15.2.1 When full-size tests are to be performed, the yield strength and wedge tensile strength or axial tensile strength, as required by Section 7, shall be determined on each sample in accordance with the appropriate methods of Test Methods F 606.

15.2.2 Full-size bolts and hex cap screws subject to tension tests shall be tested using a wedge under the head. The wedge shall be 10° for bolts 0.750-in. nominal diameter and less and 6° for bolts over 0.750-in. diameter.

15.2.3 When machined specimen tests are necessary (see Section 7), the yield strength, tensile strength, and elongation shall be determined on each sample in accordance with Test Methods F 606.

15.2.4 The hardness shall be determined in accordance with Test Methods F 606. A minimum of two readings shall be made on each sample, each of which shall conform to the specified requirements.

15.3 Corrosion Resistance—When specified on the purchase order or inquiry, corrosion tests to determine freedom
from precipitated carbides shall be performed in accordance with Practice A 262, Practice A or E as applicable.

16. Rejection and Rehearing

16.1 Unless otherwise specified, any rejection based on tests specified herein and made by the purchaser shall be reported to the manufacturer within 30 working days from the receipt of the product by the purchaser.

17. Certification and Test Reports

17.1 Certificate of Compliance—Unless otherwise specified in the purchase order, the manufacturer shall furnish certification that the product was manufactured and tested in accordance with this specification and the customer’s order and conforms to all specified requirements.

17.2 Test Reports—When specified on the order, the manufacturer shall furnish a test report showing the chemical analysis of the fasteners and the results of the last completed set of mechanical tests for each lot of fasteners in the shipment.

17.3 All certification shall indicate the purchase order number and the applicable requirements of Section 3.

18. Product Marking

18.1 Individual Products—All products except studs ⅜ in. in diameter and smaller shall be marked with a symbol identifying the manufacturer. In addition, they shall be marked with the alloy/mechanical property marking in accordance with Table 2. The manufacturer may at his option add the specific stainless alloy designation from Table 1. However, marking of the stainless alloy designation does not signify compliance with this specification. The marking shall be raised or depressed at the option of the manufacturer.

19. Packaging and Package Marking

19.1 Packaging:

19.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

19.1.2 When special packaging requirements are required by the purchaser, they shall be defined at the time of inquiry and order.

19.2 Package Marking—Each shipping unit shall include or be plainly marked with the following:

19.2.1 ASTM specification,
19.2.2 Alloy number,
19.2.3 Alloy/mechanical property marking,
19.2.4 Size,
19.2.5 Name and brand or trademark of manufacturer,
19.2.6 Number of pieces,
19.2.7 Country of origin,
19.2.8 Date of manufacture,
19.2.9 Purchase order number, and
19.2.10 Lot number, if applicable.

20. Keywords

20.1 bolts; general use; hex cap screws; stainless; studs

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry and order (see Section 3). Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Shipment Lot Testing

S1.1 When Supplementary Requirement S1 is specified on the order, the manufacturer shall make sample tests on the individual lots for shipment to ensure that the product conforms to the specified requirements.

S1.2 The manufacturer shall make an analysis of a randomly selected finished fastener from each lot of product to be shipped. Heat or lot control shall be maintained. The analysis of the starting material from which the fasteners have been manufactured may be reported in place of the product analysis.

S1.3 The manufacturer shall perform mechanical property tests in accordance with this specification and Guide F 1470 on the individual lots for shipment.

S1.4 The manufacturer shall furnish a test report for each lot in the shipment showing the actual results of the chemical analysis and mechanical property tests performed in accordance with Supplementary Requirement S1.

S2. Additional Tests

S2.1 When additional tests of mechanical properties are desired by the purchaser, the test(s) shall be made as agreed upon between the manufacturer and the purchaser at the time of the inquiry or order.

S3. Source Inspection

S3.1 When Supplementary Requirement S3 is specified on the inquiry and order, the product shall be subject to inspection by the purchaser at the place of manufacture prior to shipment. The manufacturer shall afford the inspector all reasonable facilities to satisfy that the product is being furnished in accordance with this specification. All inspections and tests shall be so conducted so as not to interfere unnecessarily with the operations of the manufacturer.
S4. Alloy Control

S4.1 When Supplementary Requirement S4 is specified on the inquiry and order, the manufacturer shall supply that alloy specified by the customer on his order with no group substitutions permitted without the written permission of the purchaser.

S5. Heat Control

S5.1 When Supplementary Requirement S5 is specified on the inquiry or order, the manufacturer shall control the product by heat analysis and identify the finished product in each shipment by the actual heat number.

S5.2 When Supplementary Requirement S5 is specified on the inquiry and order, Supplementary Requirements S1 and S4 shall be considered automatically invoked with the addition that the heat analysis shall be reported to the purchaser on the test reports.

S6. Permeability

S6.1 When Supplementary Requirement S6 is specified on the inquiry and order, the permeability of bolts, hex cap screws, and studs of Alloy Groups 1, 2, and 3 in Conditions A or AF shall not exceed 1.5 at 100 oersteds when determined in accordance with Test Methods A 342.

S7. Corrosion Resistance Tests

S7.1 When Supplementary Requirement S7 is specified on the inquiry and order, corrosion test(s) shall be performed as agreed upon between the manufacturer and the purchaser at the time of the inquiry or order.

S8. Passivation

S8.1 When Supplementary Requirement S8 is specified on the inquiry or order, the finished product shall be passivated in accordance with Practice A 380 or Specification A 967 at the option of the manufacturer.
Standard Specification for Stainless Steel Nuts

This standard is issued under the fixed designation F 594; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers the requirements for stainless steel nuts 0.25 to 1.50 in., inclusive, in nominal diameter in a number of alloys in common use and intended for service applications requiring general corrosion resistance.

1.2 Seven groups of stainless steel alloys are covered, including ten austenitic, two ferritic, four martensitic, and one precipitation hardening.

Group Alloys Condition
1 304, 305, 304L (CW) cold worked
3 384, 18–9LW, 302HQ (CW) cold worked
2 316, 316L (CW) cold worked
3 321, 347 (CW) cold worked
4 430 (CW) cold worked
5 410 (H) hardened and tempered
6 431 (H) hardened and tempered
7 630 (AH) aged hardened

A Unless otherwise specified on the inquiry and order, the choice of an alloy from within a group shall be at the discretion of the fastener manufacturer (see 6.1).
B See 4.2 for options.
C When approved by the purchaser, alloys 303, 303Se, or XM1 may be furnished.
D Sizes 0.75 in. and larger may be hot worked and solution annealed.
E When approved by the purchaser, alloy 430F may be furnished.
F When approved by the purchaser, alloy 416 or 416Se may be furnished.

1.3 Supplementary requirements of an optional nature are provided, applicable only when agreed upon by the manufacturer and the purchaser at the time of the inquiry and order.

1.4 Suitable bolts, hex cap screws, and studs for use with nuts included in this specification are covered by Specification F 593. Unless otherwise specified, all bolts, hex cap screws, and studs used with these nuts shall conform to the requirements of Specification F 593 and shall be of the same alloy group.

2. Referenced Documents

2.1 ASTM Standards:

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
A 276 Specification for Stainless Steel Bars and Shapes
A 342/A 342M Test Methods for Permeability of Feebly Magnetic Materials
A 380 Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
A 484/A 484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings
A 493 Specification for Stainless Steel Wire and Wire Rods for Cold Heading and Cold Forging
A 555/A 555M Specification for General Requirements for Stainless and Heat-Resisting Steel Wire and Wire Rods
A 564/A 564M Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes
A 571 Specification for Austenitic Ductile Iron Castings for Pressure-Containing Parts Suitable for Low-Temperature Service
A 582/A 582M Specification for Free-Machining Stainless Steel Bars
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
D 3951 Practice for Commercial Packaging
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys
F 593 Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs
F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

2.2 ASME Standards:

B1.1 Unified Inch Screw Threads

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States.
B18.2.2 Square and Hex Nuts

NOTE 1—The following ASTM standards are noted for information only as suitable sources of material for the manufacture of nuts to this specification:
Specifications A 493, A 564/A 564M, and A 582/A 582M.

3. Ordering Information

3.1 Orders for nuts under this specification shall include the following:
3.1.1 Quantity (number of pieces of each item and size),
3.1.2 Name of item,
3.1.3 Size (diameter and threads per inch),
3.1.4 Alloy group number (see 6.2.1), and
3.1.5 Condition (see 4.2).
3.1.6 Orders for nuts under this specification may include the following optional requirements:
3.1.6.1 Forming (see 4.1.1),
3.1.6.2 Composition (see 6.2),
3.1.6.3 Corrosion resistance (see 8.1),
3.1.6.4 Thread class (see 9.2),
3.1.6.5 Finish (see 10.3),
3.1.6.6 Test report (see 17.2),
3.1.6.7 Rejection (see 16.1), and
3.1.6.8 Test rejection (see 16.1), and
3.1.6.9 Special packaging (see 19.2).
3.1.7 Supplementary requirements, if any, to be specified on the order (see S1 through S8), and
3.1.8 ASTM specification and date of issue. When date of issue is not specified, fasteners shall be furnished to the latest issue.

NOTE 2—Example: 10 000 pieces, Hex Nut, 0.250 in. −20, Alloy Group 1, Condition CW, Furnish Test Report, Supplementary Requirement S3.

4. Manufacture

4.1 Manufacture:
4.1.1 Forming—Unless otherwise specified, the nuts shall be hot formed, cold formed, or machined from suitable material, at the option of the manufacturer.
4.2 Condition—The fasteners shall be furnished in the following conditions, unless specified to be furnished in one of the optional conditions:

<table>
<thead>
<tr>
<th>Alloy Group</th>
<th>Condition</th>
<th>Optional Conditions (must be specified)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 2, 3</td>
<td>CW</td>
<td>A, AF, SH</td>
</tr>
<tr>
<td>4</td>
<td>CW</td>
<td>A</td>
</tr>
<tr>
<td>5</td>
<td>H</td>
<td>HT</td>
</tr>
<tr>
<td>6</td>
<td>H</td>
<td>HT</td>
</tr>
<tr>
<td>7</td>
<td>AH</td>
<td>none</td>
</tr>
</tbody>
</table>

A—Machined from annealed or solution annealed stock thus retaining the properties of the original material; or hot formed and solution annealed.
AF—Annealed after all threading is completed.
AH—Solution annealed and age hardened after forming.
CW—Annealed and cold worked. Sizes 0.75 in. and larger may be hot worked and solution annealed.
H—Hardened and tempered at 1050°F (565°C) minimum.
HT—Hardened and tempered at 525°F (274°C) minimum.
SH—Machined from strain hardened stock.

5. Heat Treatment

5.1 Alloy Groups 1, 2, and 3 (Austenitic Alloys 303, 303Se, 304, 304L, 305, 316, 316L, 321, 347, 384, XM1, 18–9LW, and 302HQ):
5.1.1 Condition A—When Condition A is specified, the austenitic alloys shall be heated to 1900 ± 50°F (1038 ± 28°C), at which time the chromium carbide will go into the solution, be held for a sufficient time, and then be cooled at a rate sufficient to prevent precipitation of the carbide and to provide the specified properties.
5.1.2 Condition CW—When Condition CW is specified, the austenitic alloys shall be annealed as specified in 5.1.1 and then cold worked to develop the specified properties.
5.1.3 Condition AF—When Condition AF is specified, the austenitic alloys shall be annealed as specified in 5.1.1 after all cold working, including forming and threading.

5.2 Alloy Group 4 (Ferritic Alloys 430 and 430F):
5.2.1 Condition A—The ferritic alloys shall be heated to a temperature of 1450 ± 50°F (788 ± 28°C), held for an appropriate time, and then air cooled to provide the specified properties.
5.2.2 Condition CW—When Condition CW is specified, the ferritic alloys shall be annealed in accordance with 5.2.1, generally by the raw material manufacturer, and then cold worked to develop the specified properties.

5.3 Alloy Group 5 (Martensitic Alloys 410, 416, and 416Se):
5.3.1 Condition H—When Condition H is specified, the martensitic alloys 410, 416, and 416Se shall be hardened and tempered by heating to 1850 ± 50°F (1010 ± 28°C) sufficient for austenitization, held for at least ½ h and rapid air- or oil-quenched, then reheating to 1050°F (565°C) minimum for at least 1 h and air cooled to provide the specified properties.
5.3.2 Condition HT—When Condition HT is specified, the martensitic alloys 410, 416, and 416Se shall be hardened and tempered by heating to 1850 ± 50°F (1010 ± 28°C) sufficient for austenitization, held for at least ½ h and rapid air- or oil-quenched, then reheating to 525°F (274°C) minimum for at least 1 h and air cooled to provide the specified properties.

5.4 Alloy Group 6 (Martensitic Alloy 431):
5.4.1 Conditions H and HT—The martensitic alloy 431 shall be hardened and tempered as specified in 5.3.1 and 5.3.2 as applicable.

5.5 Alloy Group 7 (Precipitation Hardening Alloy 630):
5.5.1 Condition AH—The precipitation hardening alloy 630 shall be solution annealed and aged by heating to 1900 ± 25°F (1038 ± 14°C) for at least ½ h and rapid air or oil quenched to 80°F (27°C) maximum, then reheating to a temperature of 1150 ± 15°F (621 ± 8°C) for 4 h and air cooled to provide the specified properties.

6. Chemical Composition

6.1 Alloy Groups—It is the intent of this specification that fasteners shall be ordered by alloy group numbers that include alloys considered to be chemically equivalent for general purpose use. The alloy groupings are as shown below. When required, however, a specific alloy may be specified as permitted by 6.2.2.
The choice of an alloy from within a group shall be at the discretion of the fastener manufacturer as required by his method of fastener fabrication and material availability. The specific alloy used by the fastener manufacturer shall be clearly identified on any certification required by the order and shall have a chemical composition conforming to the requirements of Table 1 for the specific alloy.

6.2.2 Ordering by Specific Alloy—When ordered by a specific alloy number, the fasteners shall conform to the chemical composition limits of Table 1 for the specific alloy.

6.3 Product Analysis:

6.3.1 Product analysis may be made by the purchaser from finished nuts representing each lot. The chemical composition thus determined shall conform to the requirements of Table 1.

### TABLE 1 Chemical Requirements

<table>
<thead>
<tr>
<th>Alloy Group</th>
<th>UNS Designation</th>
<th>Alloy</th>
<th>Composition, % maximum except as shown</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Carbon</td>
</tr>
<tr>
<td></td>
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<td></td>
</tr>
<tr>
<td>Austenitic Alloys</td>
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</tr>
<tr>
<td>1</td>
<td>S30300</td>
<td>303</td>
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</tr>
<tr>
<td>1</td>
<td>S30323</td>
<td>303Se</td>
<td>0.15</td>
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<td>0.08</td>
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<td>302HQ</td>
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</tr>
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<td>S41000</td>
<td>410</td>
<td>0.15</td>
</tr>
<tr>
<td>5</td>
<td>S41600</td>
<td>416</td>
<td>0.15</td>
</tr>
<tr>
<td>5</td>
<td>S41623</td>
<td>416Se</td>
<td>0.15</td>
</tr>
<tr>
<td>Precipitation Hardening Alloy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>S17400</td>
<td>630</td>
<td>0.07</td>
</tr>
</tbody>
</table>

* At manufacturer’s option, determined only when intentionally added.
†Editorially corrected.
for the specific alloy subject to the Product Analysis Tolerance in Specification A 555/A 555M.

6.3.2 In the event of discrepancy, a referee chemical analysis of samples from each lot shall be made in accordance with 14.1.

7. Mechanical Properties

7.1 The finished fasteners shall meet the applicable mechanical properties of Table 2 for the specified alloy group and condition when tested in accordance with the mechanical property requirements as specified herein (see also Table 3).

### TABLE 2 Mechanical Property Requirements

<table>
<thead>
<tr>
<th>Stainless Alloy Group</th>
<th>Condition</th>
<th>Alloy Mechanical Property Marking</th>
<th>Nominal Diameter, in.</th>
<th>Proof Stress, ksi, min</th>
<th>Rockwell Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>F594A</td>
<td>¼ to ½ , incl</td>
<td>70</td>
<td>B85 max</td>
</tr>
<tr>
<td>(303, 304, 304L)</td>
<td>AF</td>
<td>F594B</td>
<td>½ to ⅔ , incl</td>
<td>75</td>
<td>B65 to 95, incl</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>F594C</td>
<td>¼ to ½ , incl</td>
<td>100</td>
<td>B95 to C 32, incl</td>
</tr>
<tr>
<td>(316)</td>
<td>AF</td>
<td>F594D</td>
<td>¾ to ⅔ , incl</td>
<td>85</td>
<td>B80 to C 32, incl</td>
</tr>
<tr>
<td>3</td>
<td>SH</td>
<td>F594E</td>
<td>⅔ to 1, incl</td>
<td>120</td>
<td>C24 to C 30, incl</td>
</tr>
<tr>
<td>(321, 347)</td>
<td>SH</td>
<td>F594F</td>
<td>⅔ to 1, incl</td>
<td>110</td>
<td>C20 to C 32, incl</td>
</tr>
<tr>
<td>4</td>
<td>SH</td>
<td>F594G</td>
<td>⅔ to 1, incl</td>
<td>100</td>
<td>B95 to C 30, incl</td>
</tr>
<tr>
<td>(430, 430F)</td>
<td>SH</td>
<td>F594H</td>
<td>⅔ to 1, incl</td>
<td>85</td>
<td>B90 to C 28, incl</td>
</tr>
<tr>
<td>5</td>
<td>H</td>
<td>F594I</td>
<td>⅔ to 1, incl</td>
<td>120</td>
<td>C20 to C 30, incl</td>
</tr>
<tr>
<td>(410, 416, 416Se)</td>
<td>H</td>
<td>F594J</td>
<td>⅔ to 1, incl</td>
<td>110</td>
<td>C20 to C 32, incl</td>
</tr>
<tr>
<td>6</td>
<td>H</td>
<td>F594K</td>
<td>⅔ to 1, incl</td>
<td>100</td>
<td>B95 to C 30, incl</td>
</tr>
<tr>
<td>(431)</td>
<td>H</td>
<td>F594L</td>
<td>⅔ to 1, incl</td>
<td>85</td>
<td>B90 to C 28, incl</td>
</tr>
</tbody>
</table>

### TABLE 3 Mechanical Test Requirements on Nuts

<table>
<thead>
<tr>
<th>Product</th>
<th>Proof Stress, psi</th>
<th>Tests Conducted using Full Size Product</th>
<th>Rockwell Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jam, slotted, castle nuts</td>
<td>all</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>All other nuts</td>
<td>up to 120,000</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Over 120,000</td>
<td>option A</td>
<td>option B</td>
<td></td>
</tr>
</tbody>
</table>

A Denotes mandatory tests; where options are given, all the tests under an option shall be performed. Option B tests should be made whenever feasible. Option B is the referee test in case of arbitration. Option A tests are not mandatory.

### Footnotes

- Minimum values except where shown as maximum or as a range.
- Legend of conditions:
  - A—Machined from annealed or solution annealed stock thus retaining the properties of the original stock; or hot formed and solution annealed.
  - AF—Annealed after all threading is completed.
  - SH—Solution annealed and age hardened after forming.
  - CW—Annealed and cold worked. Sizes 0.75 in. and larger may be hot worked and solution annealed.
  - H—Hardened and tempered at 1050°F (566°C) min.
  - HT—Hardened and tempered at 525°F (274°C) min.
  - SH—Machined from strain hardened stock.
8. Corrosion Resistance

8.1 Carbide Precipitation:

8.1.1 Rod, bar, and wire in the austenitic Alloy Groups 1, 2, and 3, except the free-machining grades, 303 and 303Se used to make fasteners in accordance with this specification, shall be capable of passing the test for susceptibility to intergranular corrosion as specified in Practice E of Practice A 262.

8.1.2 As stated in Practice A 262, samples may be subjected to the faster and more severe screening test in accordance with Practice A. Failing Practice A, specimens may be tested in accordance with Practice E and be considered satisfactory if passing Practice E.

9. Dimensions

9.1 Nuts:

9.1.1 Unless otherwise specified, the dimensions shall be in accordance with the requirements of ASME B18.2.2 for Hex Nuts.

9.1.2 When specified, the dimensions of nuts shall be in accordance with the requirements of ASME B18.2.2 (type as specified), or such other dimensions as may be specified.

9.2 Threads (see Table 4)—Unless otherwise specified, the nuts shall have Class 2B threads in accordance with ASME B1.1.

10. Workmanship, Finish, and Appearance

10.1 Workmanship—The nuts shall have a workmanlike finish, free of injurious burrs, seams, laps, irregular surfaces, and other defects affecting serviceability.

10.2 Surface Finish—The nuts shall have a surface finish produced in accordance with Practice A 380.

10.3 Protective Finishes—Unless otherwise specified, the nuts shall be furnished without an additive chemical or metallic finish.

11. Sampling

11.1 A lot, for the purposes of selecting test specimens, shall consist of not more than 100 000 pieces offered for inspection at one time having the following common characteristics:

11.1.1 One type of item,

11.1.2 Same alloy and condition, and

11.1.3 One nominal diameter and thread series.

12. Number of Tests and Retests

12.1 Number of Tests:

12.1.1 Mechanical Tests—The mechanical requirements of this specification shall be met in continuous mass production for stock. The manufacturer shall make sample inspections as specified below to ensure the product conforms to the specified requirements. When tests of individual shipments are required, Supplementary Requirement S1 must be specified in the inquiry and order.

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Tests</th>
<th>Acceptance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acceptance</td>
<td>Rejection</td>
</tr>
<tr>
<td></td>
<td>Number</td>
<td>Number</td>
</tr>
<tr>
<td>2 to 50</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>51 to 500</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>501 to 35 000</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>35 001 to 100 000</td>
<td>8</td>
<td>0</td>
</tr>
</tbody>
</table>

12.1.2 Corrosion Resistance Tests:

12.1.2.1 Unless otherwise specified, tests for corrosion resistance shall be in accordance with the manufacturer’s standard quality control practices. A specific number of tests is not required, but the fasteners shall be produced by manufacturing practices and subjected to tests and inspection to assure compliance with the specified requirements.

12.1.2.2 When specified on the purchase order, not less than one corrosion test to determine freedom from precipitated carbides shall be made to represent each lot.

13. Tables

### Table 4 Tensile Stress Areas and Threads per Inch

<table>
<thead>
<tr>
<th>Nominal Size, in. (D)</th>
<th>Coarse Threads–UNC</th>
<th>Fine Threads–UNF</th>
<th>8 Thread Series–8 UN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Threads/ in.</td>
<td>Stress Area, A in.²</td>
<td>Threads/ in.</td>
</tr>
<tr>
<td>¼ (0.250)</td>
<td>20</td>
<td>0.0318</td>
<td>28</td>
</tr>
<tr>
<td>⅜ (0.3125)</td>
<td>18</td>
<td>0.0524</td>
<td>24</td>
</tr>
<tr>
<td>⅜ (0.375)</td>
<td>16</td>
<td>0.0775</td>
<td>24</td>
</tr>
<tr>
<td>⅜ (0.4375)</td>
<td>14</td>
<td>0.1063</td>
<td>20</td>
</tr>
<tr>
<td>⅝ (0.500)</td>
<td>13</td>
<td>0.1419</td>
<td>20</td>
</tr>
<tr>
<td>¾ (0.5625)</td>
<td>12</td>
<td>0.1820</td>
<td>18</td>
</tr>
<tr>
<td>⅞ (0.625)</td>
<td>11</td>
<td>0.2260</td>
<td>18</td>
</tr>
<tr>
<td>⅞ (0.750)</td>
<td>10</td>
<td>0.3340</td>
<td>16</td>
</tr>
<tr>
<td>⅙ (0.875)</td>
<td>9</td>
<td>0.4620</td>
<td>14</td>
</tr>
<tr>
<td>1.000</td>
<td>8</td>
<td>0.6060</td>
<td>12</td>
</tr>
<tr>
<td>1⅛ (1.125)</td>
<td>7</td>
<td>0.7630</td>
<td>12</td>
</tr>
<tr>
<td>1⅛ (1.250)</td>
<td>7</td>
<td>0.9690</td>
<td>12</td>
</tr>
<tr>
<td>1⅛ (1.375)</td>
<td>6</td>
<td>1.1550</td>
<td>12</td>
</tr>
<tr>
<td>1⅛ (1.500)</td>
<td>6</td>
<td>1.4050</td>
<td>12</td>
</tr>
</tbody>
</table>

* Tensile stress areas are computed using the following equation:

\[
A_s = 0.7854 \left[ D \frac{0.9743}{n} \right]^2
\]

where:

- \( A_s \) = tensile stress area, in.²,
- \( D \) = nominal size (basic major diameter), in., and
- \( n \) = number of threads per inch.
12.2 Retests:
12.2.1 When tested in accordance with the required sampling plan, a lot shall be subject to rejection if any of the test specimens fail to meet the applicable test requirements.
12.2.2 If the failure of a test specimen is due to improper preparation of the specimen or to incorrect testing technique, the specimen shall be discarded and another specimen substituted.

13. Specimen Preparation

13.1 Chemical Tests — When required, samples for chemical analysis shall be taken by drilling, sawing, milling, turning, clipping, or other such methods capable of producing representative samples.
13.2 Mechanical Tests:
13.2.1 Nuts shall be tested in full section.
13.2.2 The hardness shall be determined on the top or bottom face of the nut.
13.3 Corrosion Resistance — Test specimens shall be prepared in accordance with Practices A 262.

14. Test Methods

14.1 Chemical Analysis — Chemical analysis shall be performed in accordance with Test Methods, Practices, and Terminology A 751.
14.2 Mechanical Tests:
14.2.1 The proof load or proof stress shall be determined on each sample in accordance with Test Methods F 606.
14.2.2 The hardness shall be determined in accordance with Test Methods F 606 at the top or bottom face of the nut. A minimum of two readings shall be made on each sample, each of which shall conform to the specified requirements.
14.3 Corrosion Resistance — Corrosion tests to determine freedom from precipitated carbides shall be performed in accordance with Practices A 262, Practices A or E as applicable.

15. Significance of Numerical Limits

15.1 For the purposes of determining compliance with the specified limits for properties listed in this specification, an observed value or calculated value shall be rounded in accordance with Practice E 29.

16. Rejection and Rehearing

16.1 Unless otherwise specified, any rejection based on tests specified herein and made by the purchaser shall be reported to the manufacturer within 30 working days from the receipt of the product by the purchaser.

17. Certification and Test Reports

17.1 Certificate of Compliance — Unless otherwise specified in the purchase order, the manufacturer shall furnish certification that the product was manufactured and tested in accordance with this specification and the customer’s order and conforms to all specified requirements.
17.2 Test Report — When specified on the order, the manufacturer shall furnish a test report showing the results of the last completed set of mechanical tests for each stock size in the shipment.
17.3 All certification shall indicate the purchase order number and the applicable requirements of Section 3.

18. Product Marking

18.1 Individual Nuts — All products shall be marked with a symbol identifying the manufacturer. In addition, they shall be marked with the alloy/mechanical property marking specified in Table 2. The manufacturer may at his option add the specific stainless alloy designation from Table 1. However, marking of the stainless alloy designation does not signify compliance with this standard. The marking shall be raised or depressed at the option of the manufacture.
18.2 The marking shall be on the top of the nut or on one of the wrenching flats.
18.3 Markings located on the wrenching flats shall be depressed. Markings on all other locations shall be raised or depressed at the option of the manufacturer.

19. Packaging and Package Marking

19.1 Package Marking — Each shipping unit shall include or be plainly marked with the following:
19.1.1 ASTM specification,
19.1.2 Alloy number,
19.1.3 Alloy/mechanical property marking,
19.1.4 Size,
19.1.5 Name and brand or trademark of manufacturer,
19.1.6 Number of pieces,
19.1.7 Country of origin, and
19.1.8 Purchase order number.
19.2 When special packaging requirements are specified by the purchaser, they shall be defined at the time of inquiry and order.
19.3 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.
SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied when specified by the purchaser in the inquiry and order (see 3.1.7). Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Shipment Lot Testing

S1.1 When Supplementary Requirement S1 is specified on the order, the manufacturer shall make sample tests on the individual lots for shipment to ensure that the product conforms to the specified requirements.

S1.2 The manufacturer shall make an analysis of a randomly selected finished nut from each lot of product to be shipped. Heat or lot control shall be maintained. The analysis of the starting material from which the nuts have been manufactured may be reported in place of the product analysis.

S1.3 The manufacturer shall perform mechanical property tests in accordance with this specification and Guide F 1470 on the individual lots for shipment.

S1.4 The manufacturer shall furnish a test report for each lot in the shipment showing the actual results of the chemical analysis and mechanical property tests performed in accordance with Supplementary Requirement S1.

S2. Additional Tests

S2.1 When additional tests of mechanical properties, corrosion resistance, etc; are desired by the purchaser, the test(s) shall be made as agreed upon between the manufacturer and the purchaser at the time of the inquiry or order.

S3. Source Inspection

S3.1 When Supplementary Requirement S3 is specified on the inquiry and order, the product shall be subject to inspection by the purchaser at the place of manufacture before shipment.

The manufacturer shall afford the inspector all reasonable facilities to satisfy that the product is being furnished in accordance with this specification. All inspections and tests shall be so conducted so as not to interfere unnecessarily with the operations of the manufacturer.

S4. Alloy Control

S4.1 When Supplementary Requirement S4 is specified on the inquiry and order, the manufacturer shall supply that alloy specified by the customer on his order with no group substitutions permitted without the written permission of the purchaser.

S5. Heat Control

S5.1 When Supplementary Requirement S5 is specified on the inquiry and order, the manufacturer shall control the product by heat analysis and identify the finished product in each shipment by the actual heat number.

S5.2 When Supplementary Requirement S5 is specified on the inquiry and order, Supplementary Requirements S1 and S4 shall be considered automatically invoked with the addition that the heat analysis shall be reported to the purchaser on the test reports.

S6. Permeability

S6.1 When supplementary requirement S7 is specified on the inquiry and order, the permeability of nuts of Groups 1, 2, and 3 alloys in Conditions A or F shall not exceed 1.5 at 100 oersteds when determined by Test Methods A 342.
Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

This standard is issued under the fixed designation F 606; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (\(\epsilon\)) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

\(1\) \(\text{Note—Section 3.5.1 was editorially corrected in March 2004.}\)

1. Scope

1.1 These test methods cover establishment of procedures for conducting tests to determine the mechanical properties of externally and internally threaded fasteners, washers, and rivets.

1.2 Property requirements and the applicable tests for their determination are specified in individual product standards. In those instances where the testing requirements are unique or at variance with these standard procedures, the product standard shall specify the controlling testing requirements.

1.3 These test methods describe mechanical tests for determining the following properties:

<table>
<thead>
<tr>
<th>Section</th>
<th>For Externally Threaded Fasteners:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Product Hardness</td>
</tr>
<tr>
<td></td>
<td>Proof Load</td>
</tr>
<tr>
<td></td>
<td>Method 1, Length Measurement</td>
</tr>
<tr>
<td></td>
<td>Method 2, Yield Strength</td>
</tr>
<tr>
<td></td>
<td>Method 3, Uniform Hardness</td>
</tr>
<tr>
<td></td>
<td>Axial Tension Testing of Full-Size Product</td>
</tr>
<tr>
<td></td>
<td>Wedge Tension Testing of Full-Size Product</td>
</tr>
<tr>
<td></td>
<td>Tension Testing of Machined Test Specimens</td>
</tr>
<tr>
<td></td>
<td>Total Extension at Fracture Test</td>
</tr>
<tr>
<td></td>
<td>Single Sheer Test</td>
</tr>
<tr>
<td>For Internally Threaded Fasteners:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Product Hardness</td>
</tr>
<tr>
<td></td>
<td>Proof Load Test</td>
</tr>
<tr>
<td></td>
<td>Cone Proof Load Test</td>
</tr>
<tr>
<td>For Washers and Direct Tension Indicators:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>General Requirements</td>
</tr>
<tr>
<td></td>
<td>Through Hardened Washers</td>
</tr>
<tr>
<td>For Rivets:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Product Hardness</td>
</tr>
<tr>
<td>Test for Embrittlement of Metallic-Coated Externally Threaded Fasteners</td>
<td></td>
</tr>
</tbody>
</table>

3.1 \(\text{Product Hardness—Tests shall be conducted after the removal of any surface oxide, decarburization, plating or other}\)

\(1\) These test methods are under the jurisdiction of ASTM Committee F16 on Fasteners and are the direct responsibility of Subcommittee F16.01 on Test Methods. Current edition approved Aug. 10, 2002. Published October 2002. Originally published as F 606 – 79. Last previous edition F 606 – 00.
coating. All readings shall be within the hardness values listed in the product specification. The average of all readings on the same part shall be considered as the product hardness. Test results shall conform to the product specification for the lot represented by the test specimens to be considered conforming. Test specimen preparation and hardness tests shall be conducted in accordance with Test Method E 18 for Rockwell tests, Test Method E 10 for Brinell tests, Test Method E 92 for Vickers tests, or Test Method E 384 for Microhardness tests. The method used is at the option of the manufacturer, with regards to the size and grade of the products.

3.1.1 Routine Test Locations—For testing the hardness of the finished product, the following test locations can be used:

3.1.1.1 For hex and square head bolts; test shall be conducted on the wrench flats, top of head, unthreaded shank, end of bolt or at the arbitration location.

3.1.1.2 For studs, products without parallel wrench flats and for head styles other than hex and square; tests shall be conducted on the unthreaded shank, end of the bolt or stud or at the arbitration location.

3.1.1.3 Stress relieved products (3.1.1.1 and 3.1.1.2) are measured anywhere on the surface or through the cross section. Refer to the product specification for particular test location or use the arbitration location.

3.1.1.4 The Rockwell Hardness Scale may be used for all product diameters; however, the Brinell hardness is limited to products over 1½-in. nominal diameter.

3.1.2 Laboratory Inspection—After observing 3.1 and 3.1.1, a minimum of three readings shall be taken on each sample of finished product.

3.1.3 Arbitration Test Location—For purposes of arbitration between the purchaser and seller over reported test results, hardness tests shall be conducted at the mid-radius \((r/2)\) of a transverse section through the threads taken at a distance of approximately one diameter from the point end of the bolt or one end of the stud. Four readings shall be taken from the point end of the bolt or one end of the stud. Four readings shall be taken approximately 90° to one another on the same plane, if product size permits. Smaller diameter products may also use the opposite parallel surface area of the bolt head end as sectioned above. (See Fig. 1). The use of Brinell hardness is limited to product sizes greater than 2¼-in. nominal diameter.

3.2 Tension Tests—It is preferred that bolts and studs be tested full size, and it is customary, when so testing, to specify a minimum ultimate load (or stress) in pounds-force (or pounds-force per square inch.) Paragraphs 3.2 through 3.5 apply when testing externally threaded fasteners full size. Paragraph 3.6 shall apply where the individual product specifications permit the use of machined specimens. (See Test Methods E 8.)

3.2.1 Proof Load—The proof-load test consists of stressing the product with a specified load that the product must withstand without measurable permanent set. Alternative tests for determining the ability of a fastener to pass the proof-load test are the yield strength test and the uniform hardness test. Either Method 1 (3.2.3), Method 2 (3.2.4), or Method 3 (3.2.5) may be used, but Method 1 shall be the arbitration method in case of any dispute as to acceptance of the product. (See Test Methods E 8.)

3.2.2 In both Methods 1 and 2, assemble the product in the fixture of the tension testing machine so that six complete threads (except for heavy hex structural bolts, which shall be based on four threads) are exposed between the grips. This is obtained by freely running the nut or fixture to the thread runout of the specimen and then unscrewing the specimen six full turns. For continuous thread bolts, at least six full threads shall be exposed between the fixture ends; however, for referee purposes, six full threads shall be exposed.

3.2.3 Method 1, Length Measurement—To ensure consistent and repetitive length measurements of the fastener, the threaded end and top of the bolt head shall have conical depressions made at the approximate axis or center line of the fastener. If raised or depressed markings on the head interfere with the placement of the measuring depressions, the head shall be carefully ground. The measuring instrument shall have pointed anvils which mate with the center line depressions and be capable of measuring changes in length of 0.0001 in. with an accuracy of 0.0001 in. in any 0.001 in. range. Place the

![For small screws alternate surface](image)

![Primary surface for hardness readings](image)

![FIG. 1 Hardness Arbitration Test Location](image)
fastener between the measuring anvils and rotate it approximately ¼ turn to the left center, right then center again to assure sound seating. Zero the instrument or record indicated measurement. If using a bolt extensometer, the bolt with attached extensometer may be assembled into the tension testing machine. If not, mark the fastener so it may be placed as close as possible to the same position for the second reading. Remove and assemble the fastener into the tension testing machine as outlined in 3.4. With a test speed which shall not exceed 0.12 in./min, as determined with a free-running cross head, axially load the fastener to the proof load value specified in the product specification. This load shall be maintained for a period of 10 s before releasing the load. Replace the fastener between the measuring anvils and rotate as before, stopping the mark at the same approximate position as the first reading. The measurement shall show no permanent elongation. A tolerance of ±0.0005 in. shall be allowed (for measurement error only) between the measurement made before loading and that made after loading. Variables such as straightness, thread alignment, or measurement error could result in apparent elongation of the product when the specified proof load is initially applied. In such cases, the product may be retested using a 3 % greater load, and shall be considered acceptable if there is no difference in the length measurement after this loading within a 0.0005 in. measurement tolerance as outlined.

3.2.4 Method 2, Yield Strength—Assemble the product in the testing equipment as outlined in 3.4. As the load is applied, measure and record the total elongation of the product or any part of it that includes the exposed threads to produce a load-elongation diagram. Determine the load or stress at an offset equal to 0.2 % of the length of bolt occupied by six full threads as shown in Fig. 2 (except for heavy hex structural bolts, which shall be based on four threads) by the method described in 3.6.3.1.

3.2.4.1 Method 2A, Yield Strength for Austenitic Stainless Steel and Non-ferrous Materials—Assemble the product in the testing equipment as outlined in 3.4. As the load is applied, measure and record the total elongation of the product in order to produce a load elongation diagram. Determine the load or stress at an offset equal to 0.2 % strain based on the length of the bolt between the holders as shown in Fig. 2, which will be subject to elongation under load by using the method described in 3.6.3.1.

3.2.5 Method 3, Uniform Hardness—The fasteners shall be tested for hardness as described in 3.1, and in addition, the hardness shall also be determined in the core. The difference between the mid-radius and core hardness shall be not more than 3 points on a Rockwell C Scale; and both readings must be within product specification. This test is valid for fasteners up to and including 1 in. in diameter.

3.3 Bolts or Studs Too Short for Tension Testing—Product lengths less than those shown in Table 1 for product ¼ through ¾ in. in diameter and less than three diameters in length for product above ¾ in. in diameter, or that do not have sufficient threads for proper engagement and still leave the specified number of complete threads exposed between the grips, shall be deemed too short for tension testing, and acceptance shall be based on a hardness test performed in accordance with 3.1. If tests other than product hardness are required, their requirements should be referenced in the product specification.

3.4 Axial Tension Testing of Full-Size Products:

3.4.1 Test bolts in a holder with the load axially applied between the head and a nut or suitable fixture (Fig. 2), either of which shall have sufficient thread engagement to develop the full strength of the product. Assemble the nut or fixture on the product, leaving a minimum of six complete bolt threads exposed between the grips except for heavy hex structural bolts, which shall have four complete threads exposed between the grips.

3.4.2 Test studs by assembling one end in the threaded fixture to the thread runout. For studs having unlike threads, this shall be the end with the finer pitch thread, or with the larger minor diameter. Likewise, assemble the other end of the stud in a threaded fixture, leaving six complete threads exposed...
between the grips. For continuous thread studs, at least six complete threads shall be exposed between the fixture ends. The maximum speed of the free-running cross head shall not exceed 1 in./min. When reporting the tensile strength of product, in pounds-force per square inch, calculate the thread stress area as follows:

\[ A_s = 0.7854 \left( D - \frac{0.9743}{n} \right)^2 \]

where:
- \( A_s \) = thread stress area, in.\(^2\)
- \( D \) = nominal diameter of bolt or stud, in., and
- \( n \) = number of threads per inch.

3.4.3 To meet the requirements of the test described in 3.4.1 and 3.4.2, the product shall support a load prior to fracture not less than the minimum tensile strength specified in the product specification for its size, strength, and thread series. In addition, the tensile fracture shall occur in the body or threaded section with no fracture at the junction of head and shank.

**NOTE 2—Fracture at the junction of the head and shank is prohibited at any load, including those above the minimum requirements.**

3.5.2 **Wedge Tension Testing of Studs**—When both wedge tension and proof load testing are required by the product specifications, assemble one end of the same stud previously used for proof load testing in a threaded fixture to the thread runout. For studs having unlike threads, this shall be the end with the finer pitch thread or with the larger minor diameter. Assemble the other end of the stud in a threaded wedge to the runout and then unscrew six full turns, thus leaving six complete threads exposed between the grips, as illustrated in Fig. 4. For continuous thread studs, at least six complete threads shall be exposed between the fixture ends. The angle of the wedge for the stud size and grade shall be as specified in Table 2. Assemble the stud in the testing machine and tension test to fracture, as described in 3.4. The minimum hardness of the threaded wedge shall be 45 HRC. The length of the threaded section of the wedge shall be equal to at least the diameter of the stud. To facilitate removal of the broken stud, counterbore the wedge. The thickness of the wedge at the thin side of the hole shall equal the diameter of the stud plus the depth of counterbore. The thread in the wedge shall have Class 3B tolerances, except when testing studs having an interference fit thread, in which case the wedge shall be threaded to provide a finger-free fit. The supporting fixture, as shown in Fig. 4, shall have a hole clearance over the nominal size of the stud, and shall have its top and bottom edges rounded or chamfered to the same limits specified for the hardened wedge in Table 3. To meet the requirements of this test, the stud shall support a load prior to fracture not less than the minimum tensile strength specified in the product specification for its size, grade, and thread series.

**NOTE 3—Dimensional tolerances for all test fixtures used in this test method, unless otherwise noted, shall conform to standard machining practices.**

3.6 **Tension Testing of Machined Test Specimens:**

3.6.1 Where bolts and studs cannot be tested full size, conduct tests using test specimens machined from the bolt or stud (see Test Methods E 8).

3.6.1.1 Bolts and studs 9\(\frac{1}{16}\) in. in diameter and smaller may be machined concentric with the axis of the bolt or stud. The specimen shall have a turned section as large as feasible and shall have a gage length four times the diameter of the specimen. See Fig. 5 and Fig. 6.

3.6.1.2 Bolts and studs 9\(\frac{1}{8}\) in. in diameter through 1\(\frac{1}{4}\) in. in diameter may have their shanks machined concentric with the axis of the bolt or stud, leaving the bolt head and threaded section intact as shown in Fig. 5. Alternatively, bolts and studs 9\(\frac{1}{8}\) in. in diameter through 1\(\frac{1}{4}\) in. in diameter may have their shanks machined to a test specimen with the axis of the specimen located midway between the axis and outside surface of the bolt or stud as shown in Fig. 7. Bolts of a small cross section that will not permit taking the 0.500-in. round, 2-in. gage length test specimen shall have a turned section as large

---

**TABLE 1 Minimum Length of Product Requiring Tension Testing**

<table>
<thead>
<tr>
<th>Nominal Product Size, in.</th>
<th>Minimum Length, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\frac{1}{4})</td>
<td>(\frac{5}{8})</td>
</tr>
<tr>
<td>(\frac{5}{16})</td>
<td>(\frac{3}{8})</td>
</tr>
<tr>
<td>(\frac{3}{16})</td>
<td>(\frac{1}{4})</td>
</tr>
<tr>
<td>(\frac{1}{8})</td>
<td>(\frac{1}{2})</td>
</tr>
<tr>
<td>(\frac{9}{32})</td>
<td>(\frac{3}{16})</td>
</tr>
<tr>
<td>(\frac{1}{4})</td>
<td>(\frac{1}{4})</td>
</tr>
<tr>
<td>(\frac{5}{16})</td>
<td>(\frac{3}{8})</td>
</tr>
<tr>
<td>(\frac{3}{16})</td>
<td>(\frac{5}{32})</td>
</tr>
<tr>
<td>(\frac{1}{8})</td>
<td>(\frac{7}{64})</td>
</tr>
</tbody>
</table>

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F 606 – 02\(e\)^1

---

4
as feasible and concentric with the axis of the bolt or stud. The gage length for measuring the elongation shall be four times the diameter of the specimen. Fig. 6 illustrates an example of these small-size specimens. For arbitration purposes, machined test specimens for bolts and studs 3/8 in. in diameter through 1 1/4 in. in diameter shall be machined with the axis of the specimen located midway between the center and outside surface.

\[ c = \text{clearance of hole} \]
\[ D = \text{diameter of bolt or screw} \]
\[ R = \text{radius or chamfer} \]
\[ T = \text{reference thickness of wedge at thin side of hole equals one half diameter of bolt or screw} \]
\[ W = \text{wedge angle (see Table 2)} \]

**FIG. 3 Wedge Test Details—Bolts**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4 – 1/2</td>
<td>0.030</td>
<td>0.030</td>
</tr>
<tr>
<td>5/16 – 7/16</td>
<td>0.050</td>
<td>0.060</td>
</tr>
<tr>
<td>3/8 – 1</td>
<td>0.060</td>
<td>0.080</td>
</tr>
<tr>
<td>7/8 – 1 1/4</td>
<td>0.060</td>
<td>0.125</td>
</tr>
<tr>
<td>1 1/8 – 1 1/4</td>
<td>0.094</td>
<td>0.125</td>
</tr>
<tr>
<td>1 3/4 – 2</td>
<td>0.094</td>
<td>0.225</td>
</tr>
<tr>
<td>2 1/4 – 3</td>
<td>0.125</td>
<td>0.256</td>
</tr>
</tbody>
</table>

\[ A \] Heat-treated bolts that are threaded one diameter or closer to the underside of the head, shall use a wedge angle of 6° for sizes 1/4 through 7/8 in. and 4° for sizes over 7/4 in.

3.6.1.3 Bolts and studs 1 3/8 in. in diameter and larger may have their shanks machined to the dimensions of a 0.500-in. round, 2-in. gage length test specimen with the axis of the specimen located midway between the center and outside surface of the bolt or stud as shown in Fig. 7.

3.6.1.4 Machined test specimens shall exhibit tensile strength, yield strength (or yield point), elongation, and reduction of area equal to or greater than the values of these
properties specified for the product size in the applicable product specification when tested in accordance with this section.

3.6.2 Determination of Tensile Properties:

3.6.2.1 Yield Point—Yield point is the first stress in a material, less than the maximum obtainable stress, at which an increase in strain occurs without an increase in stress. Yield point is intended for application only for materials that may exhibit the unique characteristic of showing an increase in strain without an increase in stress. The stress-strain diagram is characterized by a sharp knee or discontinuity. Determine yield point by one of the following methods:

3.6.2.2 Drop of the Beam or Halt of the Pointer Method—In this method apply an increasing load to the specimen at a uniform rate. When a lever and poise machine is used, keep the beam in balance by running out the poise at approximately a steady rate. When the yield point of the material is reached, the increase of the load will stop, but run the poise a trifle beyond the balance position, and the beam of the machine will drop for a brief but appreciable interval of time. When a machine equipped with a load-indicating dial is used, there is a halt or hesitation of the load-indicating pointer corresponding to the drop of the beam. Note the load at the “drop of the beam” or the “halt of the pointer” and record the corresponding stress as the yield point.

3.6.2.3 Autographic Diagram Method—When a sharp-kneed stress-strain diagram is obtained by an autographic recording device, take the stress corresponding to the top of the knee (Fig. 8), or the stress at which the curve drops as the yield point (Fig. 9).

3.6.2.4 Total Extension Under Load Method—When testing material for yield point and the test specimens may not exhibit

\[ C = \text{clearance of hole (see Table 3)} \]
\[ D = \text{diameter of stud} \]
\[ R = \text{radius or chamfer (see Table 3)} \]
\[ T = \text{depth of counterbore} \]
\[ W = \text{wedge angle (see Table 2)} \]
\[ E = \text{length of threaded section of wedge} = D \]
a well-defined disproportionate deformation that characterizes a yield point as measured by the drop of the beam, halt of the pointer, or autographic diagram methods described in 3.6.2.2 and 3.6.2.3, a value equivalent to the yield point in its practical significance may be determined by the following method and may be recorded as yield point: Attach a Class C or better extensometer (Note 4 and Note 5) to the specimen. When the load producing a specified extension (Note 6) is reached, record the stress corresponding to the load as the yield point, and remove the extensometer (Fig. 10).

**Note 4**—Automatic devices are available that determine the load at the specified total extension without plotting a stress-strain curve. Such devices may be used if their accuracy has been demonstrated. Multiplying calipers and other such devices are acceptable for use provided their accuracy has been demonstrated as equivalent to a Class C extensometer.

**Note 5**—Reference should be made to Practice E 83.

**Note 6**—For steel with a specified yield point not over 80,000 psi, an appropriate value is 0.005 in./in. of gage length. For values above 80,000 psi, this test method is not valid unless the limiting total extension is increased.

3.6.3 Yield Strength—Yield strength is the stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain. The deviation is expressed in terms of strain, percent offset, total extension under load, etc. Determine yield strength by one of the following methods:

3.6.3.1 Offset Method—To determine the yield strength by the “offset method,” it is necessary to secure data (autographic or numerical) from which a stress-strain diagram may be drawn. Then on the stress-strain diagram (Fig. 8) lay off $O m$ equal to the specified value of the offset, draw $m n$ parallel to $O A$, and thus locate $r$. The yield strength load $R$ is the load corresponding to the highest point of the stress-strain curve before or at the intersection of $m n$ with $r$. In reporting values of yield strength obtained by this method, the specified value of “offset” used should be stated in parentheses after the term yield strength, thus:

\[
\text{Yield strength} (0.2 \text{ % offset}) = 52,000 \text{ psi}
\]

In using this method, a minimum extensometer magnification of 250 to 1 is required. A Class B1 extensometer meets this requirement (see Note 5). See also Note 7 for automatic devices.

3.6.3.2 Extension Under Load Method—For tests to determine the acceptance or rejection of material whose stress-strain characteristics are well known from previous tests of similar material in which stress-strain diagrams were plotted, the total strain corresponding to the stress at which the specified offset (see Note 8) occurs will be known within satisfactory limits. The stress on the specimen, when this total strain is reached, is
the value of the yield strength. The total strain can be obtained satisfactorily by use of a Class B1 extensometer (Note 4 and Note 5).

NOTE 7—Automatic devices are available that determine offset yield strength without plotting a stress strain curve. Such devices may be used if their accuracy has been demonstrated.

NOTE 8—The appropriate magnitude of the extension under load will obviously vary with the strength range of the particular material under test. In general, the value of extension under load applicable to any material strength level may be determined from the sum of the proportional strain and the plastic strain expected at the specified yield strength.

The following equation is used:

\[
\text{Extension under load, in./in. of gage length} = (YS/E) + r
\]

where:

- \(YS\) = specified yield strength, psi,
- \(E\) = modulus of elasticity, psi, and
- \(r\) = limiting plastic strain, in./in.

3.6.4 Tensile Strength—Calculate the tensile strength by dividing the maximum load the specimen sustains during a tension test by the original cross-sectional area of the specimen.

3.6.5 Elongation:

3.6.5.1 Fit the ends of the fractured specimen together carefully and measure the distance between the gage marks to the nearest 0.01 in. for gage lengths of 2 in. and under, and to the nearest 0.5 % of the gage length for gage lengths over 2 in. A percentage scale reading to 0.5 % of the gage length may be used. The elongation is the increase in length of the gage length, expressed as a percentage of the original gage length. In reporting elongation values, give both the percentage increase and the original gage length.

3.6.5.2 If any part of the fracture takes place outside of the middle half of the gage length or in a punched or scribed mark within the reduced section, the elongation value obtained may not be representative of the material. If the elongation so measured meets the minimum requirements specified, no further testing is indicated, but if the elongation is less than the minimum requirements, discard the test and retest.

3.6.6 Reduction of Area—Fit the ends of the fractured specimen together and measure the diameter or the width and thickness at the smallest cross section to the same accuracy as the original dimensions. The difference between the area thus found and the area of the original cross section expressed as a percentage of the original area, is the reduction of area.

3.7 Total Extension at Fracture Test:

3.7.1 The extension at fracture \(A_L\) test shall be carried out on stainless steel and nonferrous products (bolts, screws, and studs) in the finished condition, with lengths equal to or in excess of those minimums listed in Table 1.

3.7.2 The products to be tested shall be measured for total length \(L_1\) as described in 3.7.2.1 and shown in Fig. 11.

3.7.2.1 Mark both ends of the bolt, screw, or stud using a permanent marking substance such as bluing so that measuring reference points for determining total length \(L_1\) and \(L_2\) are established. Using an open-end caliper and steel rule or other device capable of measuring to within 0.010 in., determine the total length of the product as shown in Fig. 11.

3.7.3 The product under test shall be screwed into the threaded adapter to a depth of one diameter (see Fig. 2) and load applied axially until the product fractures. The maximum speed of the free-running cross head shall not exceed 1 in./min.

3.7.4 After the product has been fractured in accordance with 3.7.3, the two broken pieces shall be fitted closely together and the overall length \(L_2\) measured (see 3.7.2.1 and Fig. 11). The total extension at fracture shall then be calculated as follows:

\[
A_L = L_2 - L_1
\]

3.7.5 The value obtained shall equal or exceed the minimum values shown in the applicable specification for the product and material type.

3.8 Single Shear Test—(Note 9) This test is intended to determine the ability of a fastener to withstand a predetermined load when applied transversely to the axis of the fastener. Shear is defined as an action or stress caused by applied forces that causes two adjacent parts of a body to slide on each other to cause separation. Shear tests may be conducted in either tension-type or compression-type single shear fixture.

3.8.1 The specimen shall be tested using hardened steel plates of sufficient thickness to preclude bearing failure. Holes in the shear plates shall be \(\frac{1}{16}\) in. larger than the nominal thread diameter of the test bolt and the holes shall be chamfered 0.010 in. to relieve sharp edges. Shear plates shall be prevented from separating by means of a suitable jig or by using a nut on the test bolt tightened finger tight.

3.8.2 The test specimen, when assembled in the shear jig, shall be mounted in a tensile-testing machine capable of applying load at a controllable rate. The grips shall be self-aligning and care shall be taken when mounting the specimen to assure that the load will be transmitted in a straight line transversely through the test bolt. Load shall be applied and continued until fracture of the bolt. Speed of testing as determined with a free-running cross head shall not be less than \(\frac{1}{4}\) in. nor greater than \(\frac{1}{2}\) in. per min.

3.8.3 The maximum load applied to the specimen, coincident with or prior to bolt fracture shall be recorded as the shear strength of the bolt. At the discretion of the testing activity, tests need not be continued to destruction provided that the specimen supports, without evidence of bolt fracture, the minimum load specified.

3.8.4 A typical test fixture for tension shear testing is shown in Fig. 12.
NOTE 9—This single-shear test is primarily used for testing Specification A 394 tower bolts which range in size from \(\frac{1}{2}\) through 1 in. diameter. For general use, the shear test practices and fixturing found in MIL STD 1312 Test 13 is used for double shear and Test 20 may be used for single shear.

4. Test Methods for Internally Threaded Fasteners

4.1 Product Hardness—For routine inspection of both heat-treated and nonheat-treated nuts, hardness shall be determined on the bearing face or wrench flats after removal of any oxide, decarburization, plating, or other coating material. Rockwell or Brinell hardness shall be used at the option of the manufacturer, taking into account the size and grade of the product.

4.1.1 The preparation of test specimens and the performance of hardness tests for Rockwell and Brinell testing shall be in conformance with the requirements of Test Methods E 18 and E 10, respectively.

4.1.2 Readings when taken on the bearing face shall be halfway between the major diameter of the thread and one corner. The reported hardness shall be the average of two hardness readings located 180° apart. The readings when taken on the wrench flats shall be one third of the distance from a corner to the center of the wrench face. The reported harness shall be the average of two readings located from opposite corners.

4.1.3 For the purpose of arbitration or for nuts too large for full size testing, where hardness alone shall determine acceptance (see 4.1.4), the following shall apply.

4.1.3.1 Sample nuts shall be sectioned laterally at approximately one half (\(\frac{1}{2}\)) of the nut height. Such samples need not be threaded, but shall be part of the manufacturing lot that was formed (in the case of heat-treated nuts, formed and heat-treated) with the product to be shipped. The preparation of the sample shall be in accordance with 4.1.1 above. All readings shall be conducted on a Rockwell Hardness testing machine. For standard hex, heavy hex and square nuts, the half of the nut not to be tested may be discarded. For special nut configurations both sections shall be identified and made available to the purchaser, if specified on the purchase order or inquiry.

4.1.3.2 Nonheat-Treated Nuts (See Fig. 13)—Two readings shall be taken 180° apart at the core (halfway between the major diameter if threaded, or blank hole if not threaded) and a corner of the nut. The reported hardness shall be the average of the two readings, and in addition both readings shall be within the hardness values listed in the product specification.

4.1.3.3 Heat-Treated Nuts (See Fig. 14)—Two sets of three readings 180° apart shall be taken. The three readings shall be taken across the section of the nut at the following positions:

- **Position 1**—As close to the major diameter, as possible, if threaded, or hole side wall if the nut is blank, but no closer than 2½ times the indent diameter.
- **Position 2**—At the core (halfway between the major diameter, if threaded, or hole side wall, if blank) and a corner of the nut.
- **Position 3**—As close to the corner of the nut as possible, but no closer than 2½ times the indent diameter.

4.1.3.4 The reported hardness shall be the average of all six readings. In addition all readings shall be within hardness values listed in the product specification.

4.1.4 Nuts exhibiting a proofload in excess of 160 000 lb may be considered, at the option of the manufacturer, as too large for full-size testing. Full-size testing is recommended whenever possible.

4.1.5 For nuts on which hardness and proof load tests are performed, acceptance based on proof load requirements shall take precedence in the event of controversy with hardness tests.

4.2 Proof Load Test—Assemble the nut to be tested on a hardened threaded mandrel (4.2.2) or a test bolt (4.2.1) as illustrated in Fig. 15(a) Tension Method or Fig. 15(b) Compression Method. The hardened test mandrel and the tension method shown in Fig. 15(a) shall be mandatory as a referee if arbitration is necessary. Apply the specified proof load for the nut against the nut. The nut shall resist this load without stripping or rupture, and shall be removable from the test bolt or mandrel by the fingers after the load is released. Occasionally it may be necessary to use a manual wrench or other means to start the nut in motion. Use of such means is permissible, provided the nut is removable by the fingers following the initial loosening of not more than one-half turn of the nut. If the threads of the mandrel or test bolt are damaged during the test, discard the test.

4.2.1 The test bolt shall have threads appropriate to the standard specified for the nut being tested and shall have a yield strength in excess of the specified proof load of the nut being tested.
4.2.2 Mandrels shall have a hardness of 45 HRC minimum and shall have threads conforming to Class 3A except that the maximum major diameter shall be the minimum major diameter plus 0.002 in. or 0.25 times the major diameter tolerance (whichever is greater) of Class 3A threads.

4.2.3 The proof load shall be determined at a free running cross head speed not exceeding 1.0 in/minute and shall be held at load for 10 s.

4.3 Cone Proof Load Test—Perform this test using a conical washer and threaded mandrel (as illustrated in Fig. 16) to determine the influence of surface discontinuities (that is, forging cracks and seams) on the load-carrying ability of hardened steel nuts through 1½ in. in diameter by introducing a simultaneous dilation and stripping action of the nut. The mandrel shall conform to the requirements of 4.2.2. The conical washer shall have a hardness of 57 HRC minimum and a hole diameter equivalent to the nominal diameter of the mandrel +0.002, −0.000 in. The contact point of the cone shall be sharp for nut sizes ½ in. and less. For sizes over ½ in., the mandrel shall conform to the requirements of 4.2.2. The proof load shall be determined at a free running cross head speed not exceeding 1.0 in/minute and shall be held at load for 10 s. Compute the cone proof load of a nut as follows:

\[
CPL = (1 - 0.30D) \times f \times A_s
\]

where:
- \(CPL\) = cone proof load, lb,
- \(D\) = nominal diameter of nut, in.,
- \(f\) = specified proof stress of nut, psi,
- \(A_s\) = tensile stress area of nut, in.\(^2\),
- \(n\) = 0.7854 \[D - (0.9743/n)\]\(^2\), and
- \(n\) = threads per inch.

To meet the requirements of the cone proof load test, the nut shall support its specified cone proof load without stripping or rupture.

5. Test Methods for Washers and Direct Tension Indicators

5.1 General Requirements:
5.1.1 All tests shall be conducted on a Rockwell hardness tester.
5.1.2 Use of a ¼ in. (6 mm) or smaller spot anvil shall be used for hardness testing of washers and direct tension indicators.
5.1.3 Readings are not to be taken on or near product markings.

5.1.4 Preparation of test specimens and the performance of hardness tests shall be performed in accordance with Test Methods E 18.

5.1.5 For arbitration purposes, a minimum of two readings 180° apart on at least one face shall be taken. (See Fig. 17.)

5.1.6 All readings shall be within the hardness values listed in the product specification, and the average of all readings shall be considered as the hardness of the product.

5.1.7 An initial reading may be used to establish that the hardness testing equipment is properly set up and that the correct scale is being used. Such readings are not used to determine conformance.

5.2 Through Hardened Washers:
5.2.1 Surface Hardness—Take hardness readings on a smooth flat portion of the washer, prepared by light grinding or polishing as necessary.

5.2.2 Core Hardness—Take hardness readings on a smooth flat portion of the washer, prepared by light grinding or polishing such that readings are taken at a minimum depth of 0.015 in. (0.38 mm) from the original surface.

5.3 Carburized Washers:
5.3.1 Surface Hardness—Take hardness readings on a smooth flat portion of the washer, using a method which prevents penetration into the core material.

5.3.2 Core Hardness—Take hardness readings on a smooth flat portion of the washer, prepared by light grinding or polishing such that readings are taken at a depth greater than the depth of case.

5.3.3 Depth of Case—Measurements of case depth shall be taken at a cross section through the rim of the washer, having been ground and etched to define the case area.

5.4 Stainless Steel and Nonferrous Washers:
5.4.1 Surface Hardness—Take hardness readings on a smooth flat portion of the washer.

5.4.2 Core Hardness—Take hardness readings on a smooth flat portion of the washer, prepared by light grinding or polishing such that readings are taken at a minimum depth of 0.015 in. (0.38 mm) from the original surface.

5.5 Direct Tension Indicators:
5.5.1 Surface Hardness—Take hardness readings on a smooth flat portion of the DTI, at a point approximately midway between the protrusion (top side) or pocket (bottom side) and the outside diameter. Prepare the DTI by light grinding or polishing as necessary.

5.5.2 Core Hardness—Take hardness readings on a smooth flat portion of the DTI, at a point approximately midway between the protrusion (top side) or pocket (bottom side) and the outside diameter. Prepare the DTI by light grinding or polishing such that readings are taken at a minimum depth of 0.015 in. (0.38 mm) from the original surface.

6. Rivets
6.1 Product Hardness—Determine hardness at the mid-radius of a transverse section of the product taken at a distance of one diameter from the point end of the rivet. Use either Brinell or Rockwell hardness tests, and measure as described in 3.1.
7. Test for Embrittlement of Metallic Coated Externally Threaded Fasteners

7.1 This is one test method for determining if embrittlement exists in a metallic coated externally threaded fastener covered by the product specifications of ASTM Committee F16.

7.2 The test fastener shall be installed in a test fixture (see Note 1 in Fig. 18) with the head positioned against the wedge, assembled with a nut, and tensioned (by means of the nut only) by any means capable of measuring tensile load. The torque method described in 7.3 is one such method. The test samples shall be tensioned to 75% of their specified minimum ultimate tensile strength. For studs with different thread pitches on either end, the finer thread pitch end shall be assembled with a nut and tested as the head end of the fastener.
7.2.1 The assembly shall remain in this tightened state for not less than 48 h, after which the test fastener shall be visually examined for embrittlement-induced failure, such as missing head.

7.2.2 The joint shall then be disassembled and the test fastener visually examined using a minimum of 20 power magnification for evidence of embrittlement failure, such as transverse cracks in the shank, threads or at the junction of head to shank.

7.2.3 For disassembly, if the torque method of tightening is used, torque shall be applied in the ON direction until the nut rotates a noticeable amount. The retightening torque with the nut in motion shall be measured and shall be no less than 90% of the initial tightening torque.

7.2.4 If a direct tension method of tightening is used, the loss of clamping strength (in pounds) over the test period shall be no more than 10% of the initial clamping load.

7.3 The test fixture shall comprise a hardened wedge (7.3.1), a plate(s) (7.3.2), and a hardened washer (7.3.3). (See Fig. 18.)

7.3.1 The wedge shall have an angle as specified in Table 4. Other dimensions and properties shall be in conformance with hardened wedges described in 3.5.1.

7.3.2 The plate(s) shall be steel and have a thickness such that, after installation and tightening, a minimum of three full threads of the test fastener will be in the grip. The hole in the plate(s) shall be as close to the major diameter of the fastener being tested as practical but not greater than the hole in the hardened washer (7.2.3).

7.3.3 The hardened washer shall be in conformance with Specification F 436.

7.4 If the torque method of tightening is used, the tightening torque shall be determined using a load-measuring device capable of measuring the actual tension induced in a fastener as the fastener is tightened. Three fasteners from the test lot shall be selected at random. Each shall be assembled into the load-measuring device, mated with a nut, and the nut tightened until a load equal to 75% of the specified minimum ultimate tensile strength of the fastener is induced. The torque required to induce this load shall be measured and the arithmetic average of the three measured torques shall be the tightening torque. The surface against which the nut is torqued should be similar in hardness and finish to that of the test fixture (Fig. 18) and use of a hardened washer (7.3.3) is recommended.

7.5 To meet the requirements of this test the fastener shall show no evidence of embrittlement failure when visually examined and the retightening torque shall not be less than 90% of the initial tightening torque.

Note 10—The nature of this test method is such that a fastener will either pass or fail as a result of being subjected to the test conditions. The qualitative nature of the test does not provide information on how close or how far a fastener is from failure. This test method is to be used for embrittlement testing on a production scale and is not to be used for analytical purposes. Test Method F 1624 can be used as an analytical method to test fastener products in cases of uncertainty, or where quantitative or analytical data are required. Test Method F 1624 is not suited for embrittlement testing on a production scale due to the time and costs associated with performing the test.
A1. TEST METHOD FOR MEASURING COMPRESSION LOADS (ALL FINISHES) ON DIRECT TENSION INDICATORS COVERED BY SPECIFICATION F 959

A1.1 Testing Apparatus

A1.1.1 Test the direct tension indicators in an apparatus described herein that is capable of determining their performance characteristics with sufficient accuracy.

A1.1.2 Testing apparatus shall include a compression loading system, top and bottom bearing blocks, and support blocks that allow each direct tension indicator to be calibrated using a direct reading gage.

A1.1.3 The testing apparatus shall conform to the requirements of Practices E 4. The loads used in determining compressive loads shall be within the verified loading range of the testing machine in accordance with Practices E 4.

A1.1.4 The direct reading gage of the testing apparatus shall be capable of measuring the gap variation to within 0.0005 in.

NOTE A1.1—Because of acceptable variations in bolt dimensions and coating characteristics, bolts cannot be used as a means of gaging the direct tension indicator measured minimum and maximum performance.
A1.2 Compression Loading System

A1.2.1 The compression loading system shall transmit a compressive load axially from the testing apparatus to the direct tension indicator. The bottom bearing block of the loading system must be able to accept the cylindrical protrusions of the direct tension indicator support blocks.

A1.2.2 Maintain the compression loading system in good operating condition and use only in the proper loading range.

A1.3 Support Blocks

A1.3.1 Support blocks shall be grooved on one side so that the direct reading gage can be zeroed without compressing the direct tension indicator protrusions. (See Fig. A1.1.) Thus, the exact thickness of the direct tension indicator being tested is taken into account, and the flat surface of the side of the direct tension indicator having protrusions is made to relate exactly to the zero point of the gage that shall react on the center of the direct tension indicator support block.

A1.3.2 Support blocks shall have a minimum Rockwell hardness of 50 HRC.

A1.3.3 Support blocks shall conform to the dimensions shown in Fig. A1.2.

A1.3.4 The surfaces of support blocks shall be parallel to within 0.0002 in. across the diameter of the support block.

A1.4 Bearing Blocks

A1.4.1 The upper bearing block shall have a minimum diameter of 3 in.

A1.4.2 Bearing blocks shall have a minimum Rockwell hardness of 50 HRC.

A1.4.3 The upper and bottom bearing block surfaces shall be parallel to within 0.0005 in. across the width of the support block.

A1.5 Calibration

A1.5.1 Calibrate the testing apparatus and its direct reading gage at least once per year.

A1.5.2 Retain the calibrated test data.

A1.6 Test Procedure

A1.6.1 Select the support block corresponding to the size and type of direct tension indicator to be tested.

A1.6.2 The direct reading gage spindle shall be in contact with the center of the direct tension indicator support block during the test. (See Fig. A1.3.)

A1.6.3 Zero Direct Reading Gage—Place the direct tension indicator, with protrusions facing down, into the grooves of the support block. Apply compression load equal to the minimum required load for the size and type of direct tension indicator being tested. Set the direct reading gage at zero. Release the load and remove the direct tension indicator. See Step 1 of Fig. A1.3.

A1.6.4 Invert the support block so that Side A with the groove is facing down.

A1.6.5 Measure Compression Load:

A1.6.5.1 Place the flat surface of the direct tension indicator against side B of the support block with protrusions facing up. Apply compression load until the gage reading is the test gap specified for the size, type, and surface condition of the direct tension indicator being tested. See Step 2 of Fig. A1.3.

A1.6.5.2 Apply the compression load at a rate such that the direct tension indicator is compressed within 30 s from the time the compression load is first applied until the proper gap is achieved.

A1.6.6 Read and Record—Read the compression load within 5 s of reaching the test gap and record the results.
Direct Tension Indicator

Size | C in. max | C in. min | E in. max | E in. min | F in. max | F in. min
--- | --- | --- | --- | --- | --- | ---
1/2 | 0.485 | 0.475 | 0.130 | 0.080 | 0.96 | 0.91
5/8 | 0.615 | 0.605 | 0.145 | 0.095 | 1.15 | 1.10
3/4 | 0.735 | 0.725 | 0.150 | 0.100 | 1.34 | 1.29
1 | 0.855 | 0.845 | 0.165 | 0.115 | 1.54 | 1.49
1 1/4 | 1.085 | 1.075 | 0.165 | 0.115 | 1.93 | 1.88
1 1/4 | 1.225 | 1.215 | 0.165 | 0.115 | 2.12 | 2.07
1 1/2 | 1.355 | 1.345 | 0.165 | 0.115 | 2.31 | 2.26
2 | 1.475 | 1.465 | 0.165 | 0.115 | 2.51 | 2.46

FIG. A1.2 Support Block Dimensions

FIG. A1.3 Steps for Determining Compression Load

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This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 These test methods cover establishment of procedures for conducting tests to determine the mechanical properties of metric externally and internally threaded fasteners, washers, and rivets.

1.2 Property requirements and the applicable tests for their determination are specified in individual product standards. In those instances where the testing requirements are unique or at variance with these standard procedures, the product shall specify the controlling testing requirements.

1.3 These test methods describe mechanical tests for determining the following properties:

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<th>Tests</th>
<th>Section</th>
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<td>Product Hardness</td>
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<td>Total Extension at Fracture Test</td>
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<td>For Internally Threaded Fasteners:</td>
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<tr>
<td>Product Hardness</td>
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<td>Cone Proof Load Test</td>
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<td>For Washers and Direct Tension Indicators:</td>
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<td>Annex A1</td>
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1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of all of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

NOTE: These test methods are the metric companion of Test Methods F 606.

2. Referenced Documents

2.1 ASTM Standards:

E 8M Test Methods for Tension Testing of Metallic Materials [Metric]²
E 10 Test Method for Brinell Hardness of Metallic Materials²
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials²
E 83 Practice for Verification and Classification of Extensometers²
E 92 Test Method for Vickers Hardness of Metallic Materials²
E 384 Test Method for Microindentation Hardness of Materials²
F 436M Specification for Hardened Steel Washers [Metric]³
F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets³
F 1624 Test Method for Measurement of Hydrogen Embrittlement in Steel by the Incremental Loading Technique⁴

3. Test Methods for Externally Threaded Fasteners

3.1 Product Hardness—Tests shall be conducted after the removal of any surface oxide, decarburization, plating or other coating. All readings shall be within the hardness values listed

¹ These test methods are under the jurisdiction of ASTM Committee F16 on Fasteners and are the direct responsibility of Subcommittee F16.01 on Test Methods.

² Annual Book of ASTM Standards, Vol 03.01.

³ Annual Book of ASTM Standards, Vol 01.08.

⁴ Annual Book of ASTM Standards, Vol 15.03.
in the product specification. The average of all readings on the same part shall be considered as the product hardness. Test results shall conform to the product specification for the lot represented by the test specimens to be considered conforming. Test specimen preparation and hardness tests shall be conducted in accordance with Test Method E 18 for Rockwell tests, Test Method E 10 for Brinell tests, Test Method E 92 for Vickers tests, or Test Method E 384 for Microhardness tests. The method used is at the option of the manufacturer, with regards to the size and grade of the products.

3.1.1 Routine Test Locations—For testing the hardness of the finished product, the following test locations can be used:

3.1.1.1 For hex and square head bolts, test shall be conducted on the wrench flats, top of head, unthreaded shank, end of bolt or at the arbitration location.

3.1.1.2 For studs, products without parallel wrench flats, and for head styles other than hex and square, tests shall be conducted on the unthreaded shank, end of the bolt or stud or at the arbitration location.

3.1.1.3 Stress-relieved products (see 3.1.1.1 and 3.1.1.2) are measured anywhere on the surface or through the cross section. Refer to the product specification for particular test location or use the arbitration location.

3.1.1.4 The Rockwell hardness scale may be used for all product diameters; however, the Brinell hardness is limited to products over 30 mm nominal diameter.

3.1.2 Laboratory Inspection—After observing 3.1 and 3.1.1, a minimum of three readings shall be taken on each sample of finished product.

3.1.3 Arbitration Test Location—For purposes of arbitration between the purchaser and seller over reported test results, hardness tests shall be conducted at the mid-radius ($r/2$) of a transverse section through the threads taken at a distance of approximately one diameter from the point end of the bolt or one end of the stud. Four readings shall be taken approximately 90° to one another on the same plane, if product size permits. Smaller diameter products may also use the opposite parallel surface area of the bolt head end as sectioned above. (See Fig. 1). The use of Brinell hardness is limited to product sizes greater than 48 mm nominal diameter.

3.2 Tension Tests—It is preferred that fasteners and studs be tested full size, and it is customary, when so testing to specify a minimum ultimate load in kilonewtons (or stress in megapascals). Paragraphs 3.2 through 3.5 apply when testing externally threaded fasteners full size. Paragraph 3.6 shall apply where the individual product specifications permit the use of machined specimens. (See Test Methods E 8M.)

3.2.1 Proof Load—The proof-load test consists of stressing the product with a specified load that the product must withstand without measurable permanent set. Alternatives that determine the ability of a fastener to pass the proof-load test are the yield strength test and the uniform hardness test. Any of these tests may be used, but the proof-load test (3.2.3) shall be the arbitration method in case of any dispute. (See Test Methods E 8M.)

3.2.2 In both Methods 1 and 2, assemble the product in the fixture of the tension testing machined so that six complete threads (except for heavy hex structural bolts, which shall be based on four threads) are exposed between the grips. This is obtained by freely running the nut or fixture to the thread runout of the specimen and then unscrewing the specimen six full turns. For continuous threaded fasteners, at least six full threads shall be exposed.

3.2.3 Test Method 1, Length Measurement—To ensure consistent and repetitive length measurements of the fastener, the threaded end and top of the bolt head shall have conical depressions made at the approximate axis or center line of the fastener. If raised or depressed markings on the head interfere with the placement of the measuring depressions, the head shall be carefully ground. The measuring instrument shall have pointed anvils that mate with the center line depressions and be capable of measuring changes in length of 0.0025 mm with an accuracy of 0.0025 mm in any 0.025 mm range. Place the fastener between the measuring anvils and rotate it approximately $1/4$ turn to the left center, right then center again to assure sound seating. Zero the instrument or record indicated measurement. If using a bolt extensometer, the bolt with attached extensometer may be assembled into the tension testing machine. If not, mark the fastener so it may be placed as close as possible to the same position for the second reading.
Remove and assemble the fastener into the tension testing machine as outlined in 3.4. With a test speed which shall not exceed 3 mm/min, as determined with a free-running cross head, axially load the fastener to the proof load value specified in the product specification. This load shall be maintained for a period of 10 s before releasing the load. Replace the fastener between the measuring anvils and rotate as before, stopping with the mark at the same approximate position as the first reading. The measurement shall show no permanent elongation. A tolerance of ± 0.013 mm shall be allowed (for measurement error only) between the measurement made before loading and that made after loading. Variables such as straightness, thread alignment, or measurement error could result in apparent elongation of the product when the specified proof load is initially applied. In such cases, the product may be retested using a 3 % greater load, and shall be considered acceptable if there is no difference in the length measurement after this loading within a 0.013-mm measurement tolerance as outlined.

3.2.3.1 Proof Load-Speed and Time of Loading—When using Method 1, the speed of testing, as determined with a free-running cross head, shall not exceed 3 mm/min, and the proof load shall be maintained for a period of 10 s before releasing the load.

3.2.4 Method 2, Yield Strength—Assemble the product in the testing equipment as outlined in 3.4. As the load is applied, measure and record the total elongation of the product or any part of it that includes the exposed threads to produce a load-elongation diagram. Determine the load or stress at an offset equal to 0.2 % of the length of fastener occupied by six full threads as shown in Fig. 2, (except for heavy hex structural bolts, which shall be based on four threads) by the method described in 3.6.3.1.

3.2.4.1 Method 2A, Yield Strength for Austenitic Stainless Steel and Nonferrous Materials—Assemble the product in the testing equipment as outlined in 3.4. As the load is applied, measure and record the total elongation of the product in order to produce a load elongation diagram. Determine the load or stress at an offset equal to 0.2 % strain, based on the length of the bolt between the holders as shown in Fig. 2, which will be subject to elongation under load, by using the method described in 3.6.3.1.

3.2.5 Method 3, Uniform Hardness—The fasteners shall be tested for hardness as described in 3.1, and in addition, the hardness shall also be determined in the core. The difference between the mid-radius and core hardness shall be not more than three points on a Rockwell C Scale; and both readings must be within product specification.

Note 2—This test is valid for fasteners up to and including 25 mm in diameter.

3.3 Fasteners and Studs Too Short for Tension Testing—Product lengths less than those shown in Table 1 for product 5 through 20 mm in diameter and less than 3 diameters in length for product greater than 20 mm in diameter, or that do not have sufficient threads for proper engagement, and still leave the specified number of complete threads exposed between the grips, shall be deemed too short for tension testing, and acceptance shall be based on a hardness test performed in accordance with 3.1. If tests other than product hardness are required, their requirements should be referenced in the product specification.

3.4 Axial Tension Testing of Full Size Products:

3.4.1 Test fasteners in a holder with a load axially applied between the head and a nut or suitable fixture (see Fig. 2), either of which shall have sufficient thread engagement to develop the full strength of the product. Assemble the nut or fixture on the product, leaving six complete fastener threads exposed between the grips (except for heavy hex structural fastener, which shall have four threads exposed between grips).

3.4.2 Test studs by assembling one end of the threaded fixture to the thread runout. For studs having unlike threads, this shall be the end which has the finer pitch thread, or with the larger minor diameter. Likewise, assemble the other end of...
the stud in the threaded fixture, leaving six complete threads exposed between the grips. For continuous studs, at least six complete threads shall be exposed between the fixture ends. The maximum speed of the free running cross head shall not exceed 25 mm/min. When reporting the tensile strength of the product, calculate the thread stress area as follows:

\[ A_s = 0.7854 \left( D - 0.938P \right)^2 \]  

where:
- \( A_s \) = thread stress area, mm²
- \( D \) = nominal diameter of the fasteners or stud, mm
- \( P \) = thread pitch, mm

3.4.3 To meet the requirements of the test described in 3.4.1 and 3.4.2, the product shall support a load prior to fracture not less than the minimum tensile strength specified in the product specification for its size, property class, and thread series. In addition, fracture shall occur in the body or the threaded section with no fracture at the juncture of the body and head.

3.5 **Wedge Tension Testing of Full-Size Product**—The wedge tensile strength of a hex or square-head fastener, socket-head cap screw, (with the exception of socket button or flat countersunk head products) or stud is the tensile load that the product is capable of sustaining when stressed with a wedge under the head. The purpose of this test is to obtain the tensile strength and demonstrate the “head quality” and ductility of the product.

3.5.1 **Wedge Tension Testing of Fasteners**—Determine the ultimate load of the fastener as described in 3.4 except place a wedge under the fastener head. When both wedge and proof load testing are required by the product specification use the proof load-tested fastener for wedge testing. The wedge shall have a minimum hardness of 45 HRC. Additionally, the wedge shall have a minimum thickness of one half the nominal fastener diameter (measure at the thin side of the hole, Fig. 3). The wedge shall have an included angle as shown in Table 1 for the product type being tested. The hole in the wedge shall have a clearance over the nominal size of the fastener, and its edges top and bottom shall be rounded as specified in Table 2. The minimum outside dimension of the wedge shall be such that during the test no corner loading of the product head (adjacent to the wedge) shall occur. (See head orientation in Fig. 3). The bolt shall be tension tested to fracture. The fastener shall be tension tested to fracture. To meet the requirements of this test, the fastener shall support a load prior to fracture not less than the minimum tensile strength specified in the product specification for the applicable size, property class, and thread series. In addition, the fracture shall occur in the body or threaded portion with no fracture at the junction of head and shank.

3.5.2 **Wedge Tension Testing of Studs**—When both wedge tension and proof load testing are required by the product specification, assemble one end of the same stud previously used for proof load testing in a threaded fixture to the thread runout. For studs having uneven threads, this shall be the end with the finer pitch thread or with the larger minor diameter. Assemble the other end of the stud in a threaded wedge to the runout and then unscrew six full turns, leaving six complete threads exposed between the grips (see Fig. 4). For continuous threaded studs, at least six full threads shall be exposed between the fixture ends. The angle of the wedge for the stud size and property class shall be as specified in Table 1. Assemble the stud in the testing machine and tension test to fracture, as described in 3.4. The minimum hardness of the threaded wedge shall be 45 HRC. The length of the threaded section of the wedge shall be equal to at least the diameter of the stud. To facilitate removal of the broken stud, counterbore the wedge. The thickness of the wedge at the thin side of the hole shall equal the diameter of the stud plus the depth of the counterbore. The thread in the wedge shall have Class 4H6H tolerance, except when testing studs having an interference fit thread, in which case the wedge will have to be threaded to provide a finger-free fit. The supporting fixture (Fig. 4), shall have a hole clearance over the nominal size of the stud, and shall have its top and bottom edges rounded or chamfered to the same limits specified for the hardened wedge in Table 2. To meet the requirements of this test, the stud shall support a load prior to fracture not less than the minimum tensile strength specified in the product specification for its size, property class, and thread series. The fracture shall occur in the threaded section or in the body if the stud does not have a continuous thread.

3.6 **Tension Testing of Machined Test Specimens**—Where fasteners and studs cannot be tested full size, conduct tests using test specimens machined from the fastener or stud (see Test Methods E 8M).

3.6.1 Fasteners and studs shall have their shanks machined to the dimensions shown in Fig. 5. The reduction of the shank diameter of heat-treated fasteners and studs with nominal diameters larger than 16 mm shall not exceed 25 % of the original diameter of the product. Alternatively, fasteners 16 mm in diameter or larger may have their shanks machined to a test specimen with the axis of the specimen located midway between the axis and outside surface of the fastener as shown in Fig. 6. In either case, machined test specimens shall exhibit tensile strength, yield strength (or yield point), elongation, and reduction of area equal to or greater than the values of these properties specified for the product size in the applicable product specification when tested in accordance with this section.

**Note:**—Dimensional tolerances for all test fixtures used in this test method, unless otherwise noted, shall conform to standard machining practices.

3.6.2 **Determination of Tensile Properties:**

3.6.2.1 **Yield Point**—Yield point is the first stress in a material, less than the maximum obtainable stress, at which an
increase in strain occurs without an increase in stress. Yield point is intended for application only for material that may exhibit the unique characteristic of showing an increase in strain without an increase in stress. The stress-strain diagram is characterized by a sharp knee or discontinuity. Determine yield point by one of the following methods.

3.6.2.2 Drop of the Beam or Halt of the Pointer Method—In this method apply an increasing load to the specimen at a uniform rate. When a lever and poise machine is used, keep the beam in balance by running out the poise at approximately a steady rate. When the yield point of the material is reached, the increase of the load will stop, but run the poise a small amount beyond the balance position, and the beam of the machine will drop for a brief interval of time. When a machine equipped with a load-indicating dial is used, there is a halt or hesitation of the load-indicating pointer which corresponds to the drop of the beam. Record the load at the “drop of the beam” or the “halt of the pointer.” This is the yield point of the fastener or stud.

3.6.2.3 Autographic Diagram Method—When a sharp-kneed stress-strain diagram is obtained by an autographic device, take the stress corresponding to the top of the knee (see Fig. 7) or the stress at which the curve drops as the yield point (see Fig. 8).

3.6.2.4 Total Extension Under Load—When testing material for yield point and the test specimens may not exhibit a well-defined disproportionate deformation that characterizes a yield point as measured by the previous methods, a value

$C = \text{clearance of hole (Table 2)}$,

$D = \text{diameter of fastener}$,

$R = \text{radius of chamfer (Table 2)}$,

$T = \text{reference thickness of wedge at thin side of hole, equals one half diameter of fastener}$, and

$W = \text{wedge angle (Table 1)}$.

![FIG. 3 Wedge Test Details—Fasteners](image)

**TABLE 2 Tensile Test Wedge Hole Clearance—Details**

<table>
<thead>
<tr>
<th>Nominal Produce Diameter, mm</th>
<th>Nominal Clearance in Hole, mm</th>
<th>Nominal Radius on Corners of Hole, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>To 6</td>
<td>0.50</td>
<td>0.70</td>
</tr>
<tr>
<td>Over 6–12</td>
<td>0.80</td>
<td>0.80</td>
</tr>
<tr>
<td>Over 12–20</td>
<td>1.60</td>
<td>1.30</td>
</tr>
<tr>
<td>Over 20–36</td>
<td>3.20</td>
<td>1.60</td>
</tr>
<tr>
<td>Over 36</td>
<td>3.20</td>
<td>3.20</td>
</tr>
</tbody>
</table>
equivalent to the yield point in its practical significance may be determined by the following method and may be recorded as yield point. Attach a Class C or better extensometer (Notes 5 and 6) to the specimen. When the load producing a specified extension (Note 7) is reached, record the stress corresponding to the load as the yield point and remove the extensometer (see Fig. 9).

**NOTE 5**—Automatic devices are available that determine the load at the specified total extension without plotting a stress-strain curve. Such a device may be used if its accuracy has been demonstrated. Multiplying calipers and other such devices are acceptable for use provided their accuracy has been demonstrated as equivalent to a Class C extensometer.

**NOTE 6**—Reference should be made to Practice E 83.

**NOTE 7**—For steel with a specified yield point not over 550 MPa an appropriate value is 0.13 mm/mm of gage length. For values above 550 MPa this method is not valid unless the limiting total extension is increased.

3.6.3 **Yield Strength**—Yield strength is the stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain. The deviation is expressed in terms of strain, percent of offset, total extension under load, etc. The determination of yield strength may be determined by one of the following methods.

3.6.3.1 **Offset Method**—To determine the yield strength by the offset method, it is necessary to secure data (autographic or numerical) from which a stress-strain diagram may be drawn. Then on the stress-strain diagram (see Fig. 7) lay off, Om, equal to the specified value of the offset, draw mn parallel to OA and thus locate r. The yield strength load, R, is the load corresponding to the highest point of the stress-strain curve before or at the intersection of mn and r. In reporting values of yield strength obtained by this method, the specified value of “offset” used should be stated in parenthesis after the term yield strength, thus:

\[ \sigma = \frac{F}{A} \]

\[ \epsilon = \frac{\Delta L}{L_0} \]

\[ \Delta L = \frac{\sigma}{E} \]

\[ F = \sigma A \]

\[ A = \frac{\pi D^2}{4} \]

\[ \Delta L = \frac{\pi D^2}{4} \frac{\sigma}{E} \]

\[ \sigma = \frac{F}{\frac{\pi D^2}{4}} = \frac{4F}{\pi D^2} \]

\[ \epsilon = \frac{\Delta L}{L_0} = \frac{\frac{\pi D^2}{4} \frac{\sigma}{E}}{L_0} = \frac{\pi D^2 \sigma}{4EL_0} \]

\[ \frac{\pi D^2 \sigma}{4EL_0} = \frac{F}{\frac{\pi D^2}{4}} = \frac{4F}{\pi D^2} \]

\[ \frac{\pi D^2 \sigma}{4EL_0} = \frac{4F}{\pi D^2} \]

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\[ \frac{\pi D^2 \sigma}{4EL_0} = \frac{4F}{\pi D^2} \]

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\[ \frac{\pi D^2 \sigma}{4EL_0} = \frac{4F}{\pi D^2} \]

\[ \frac{\pi D^2 \sigma}{4EL_0} = \frac{4F}{\pi D^2} \]

\[ \sigma = \frac{4F}{\pi D^2} \]

\[ \epsilon = \frac{\Delta L}{L_0} = \frac{\frac{\pi D^2}{4} \frac{\sigma}{E}}{L_0} = \frac{\pi D^2 \sigma}{4EL_0} \]

\[ \frac{\pi D^2 \sigma}{4EL_0} = \frac{4F}{\pi D^2} \]

\[ \frac{\pi D^2 \sigma}{4EL_0} = \frac{4F}{\pi D^2} \]

\[ \sigma = \frac{4F}{\pi D^2} \]

\[ \epsilon = \frac{\Delta L}{L_0} = \frac{\frac{\pi D^2}{4} \frac{\sigma}{E}}{L_0} = \frac{\pi D^2 \sigma}{4EL_0} \]

\[ \frac{\pi D^2 \sigma}{4EL_0} = \frac{4F}{\pi D^2} \]

\[ \frac{\pi D^2 \sigma}{4EL_0} = \frac{4F}{\pi D^2} \]

\[ \sigma = \frac{4F}{\pi D^2} \]

\[ \epsilon = \frac{\Delta L}{L_0} = \frac{\frac{\pi D^2}{4} \frac{\sigma}{E}}{L_0} = \frac{\pi D^2 \sigma}{4EL_0} \]

\[ \frac{\pi D^2 \sigma}{4EL_0} = \frac{4F}{\pi D^2} \]

\[ \frac{\pi D^2 \sigma}{4EL_0} = \frac{4F}{\pi D^2} \]

\[ \sigma = \frac{4F}{\pi D^2} \]

\[ \epsilon = \frac{\Delta L}{L_0} = \frac{\frac{\pi D^2}{4} \frac{\sigma}{E}}{L_0} = \frac{\pi D^2 \sigma}{4EL_0} \]

\[ \frac{\pi D^2 \sigma}{4EL_0} = \frac{4F}{\pi D^2} \]

\[ \frac{\pi D^2 \sigma}{4EL_0} = \frac{4F}{\pi D^2} \]

\[ \sigma = \frac{4F}{\pi D^2} \]

\[ \epsilon = \frac{\Delta L}{L_0} = \frac{\frac{\pi D^2}{4} \frac{\sigma}{E}}{L_0} = \frac{\pi D^2 \sigma}{4EL_0} \]

\[ \frac{\pi D^2 \sigma}{4EL_0} = \frac{4F}{\pi D^2} \]

\[ \frac{\pi D^2 \sigma}{4EL_0} = \frac{4F}{\pi D^2} \]

\[ \sigma = \frac{4F}{\pi D^2} \]

\[ \epsilon = \frac{\Delta L}{L_0} = \frac{\frac{\pi D^2}{4} \frac{\sigma}{E}}{L_0} = \frac{\pi D^2 \sigma}{4EL_0} \]

\[ \frac{\pi D^2 \sigma}{4EL_0} = \frac{4F}{\pi D^2} \]

\[ \frac{\pi D^2 \sigma}{4EL_0} = \frac{4F}{\pi D^2} \]

\[ \sigma = \frac{4F}{\pi D^2} \]
Yield strength (0.2 % offset) = 360 MPa

In using this method, a minimum extensometer magnification of 250 to 1 × is required. A Class B1 extensometer meets this requirement (see Note 6). See Note 8 for automatic devices.

3.6.3.2 Extension Under Load Method—For tests to determine the acceptance or rejection of material whose stress-strain characteristics are well known from previous tests of similar material in which stress-strain diagrams are plotted, the total strain corresponding to the stress at which the specified offset (see Note 9) occurs will be known within satisfactory limits. The stress on the specimen, when total strength is reached, is the value of the yield strength. The total strain can be obtained satisfactorily by use of a Class B1 extensometer (see Notes 5 and 6).

Note 8—Automatic devices are available that determine offset yield strength without plotting a stress-strain curve. Such devices may be used if their accuracy has been demonstrated.

Note 9—The appropriate magnitude of the extension under load will obviously vary with the strength range of the particular material under test. In general, the value of extension under load applicable to any material strength level may be determined from the sum of the proportional strain and the plastic strain expected at the specified yield strength. The following equation shall be used:

\[
\text{Extension under load, mm/mm of gage length} = \frac{YS}{E} = r
\]

where:
- \(YS\) = specified yield strength, MPa,
- \(E\) = modulus of elasticity, MPa,
- \(r\) = limiting plastic strain, mm/mm.

3.6.4 Tensile Strength—Calculate the tensile strength by dividing the maximum load the specimen sustains during a tension test by the original cross-sectional area of the specimen.

3.6.5 Elongation:

3.6.5.1 Fit the ends of the fractured specimen together carefully and measure the distance between the gage marks to the nearest 0.25 mm for gage lengths of 50 mm or under, and to the nearest 0.5 mm of the gage length for gage lengths over 50 mm. A percentage scale reading to 0.5 % of the gage length may be used. The elongation is the increase in length of the gage length, expressed as a percentage of the original gage length. In reporting elongation values, give both the percentage increase and the original gage length.

3.6.5.2 If any part of the fracture takes place outside the middle half of the gage length or in a punched or scribed mark with the reduced section, the elongation value obtained may not be representative of the material. If the elongation so measured meets the minimum requirements specified, no further testing is indicated, but if the elongation is less than the minimum requirements, discard the test and retest.

3.6.6 Reduction of Area—Fit the ends of the fractured specimen together and measure the mean diameter or the width and thickness at the smallest cross-section to the same accuracy as the original dimensions. The difference between the area thus found and the area of the original cross-section expressed as a percentage of the original area, is the reduction in area.

3.7 Total Extension at Fracture Test:

3.7.1 The extension at fracture \( (A_L) \) test shall be carried out on stainless steel and nonferrous products in the finished condition, with lengths equal to or in excess of those minimums listed in Table 3.

3.7.2 The products to be tested shall be measured for total length \( (L_1) \) as described in 3.7.2.1 and shown in Fig. 10.

### TABLE 3 Minimum Length of Product Requiring Tension Testing

<table>
<thead>
<tr>
<th>Nominal Product Diameter, mm</th>
<th>Minimum Length, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>6</td>
<td>14</td>
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<tr>
<td>8</td>
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<td>10</td>
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<tr>
<td>12</td>
<td>30</td>
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<tr>
<td>14</td>
<td>35</td>
</tr>
<tr>
<td>16</td>
<td>40</td>
</tr>
<tr>
<td>20</td>
<td>45</td>
</tr>
<tr>
<td>Over 20</td>
<td>3D^A</td>
</tr>
</tbody>
</table>

^A The D equals the nominal diameter of the product.
3.7.2.1 Mark both ends of the fastener or stud using a permanent marking substance such as bluing so that measuring reference points for determining total length $L_1$ and $L_2$ are established. Using an open end caliper and steel rule or other device capable of measuring to within 0.25 mm determine the total length of the product as shown in Fig. 10.

3.7.3 The product under test shall be screwed into the threaded adapter to a depth of one diameter (see Fig. 2) and load applied axially until the product fractures. The maximum speed of the free-running cross head shall not exceed 25 mm/min.

3.7.4 After the product has been fractured in accordance with 3.7.3, the two broken pieces shall be fitted closely together and the overall length ($L_2$) measured (see 3.7.2.1 and Fig. 10). The total extension at fracture shall then be calculated as follows:

$$A_L = L_2 - L_1$$

(4)

3.7.5 The value obtained shall equal or exceed the minimum values shown in the applicable specification for the product and material type.

4. Test Methods for Internally Threaded Fasteners

4.1 Product Hardness—For routine inspection of both heat-treated and nonheat-treated nuts, hardness shall be determined on the bearing face or wrench flats after removal of any oxide, decarburization, plating, or other coating material. Rockwell or Brinell hardness shall be used at the option of the manufacturer, taking into account the size and grade of the product.

4.1.1 The preparation of test specimens and the performance of hardness tests for Rockwell and Brinell testing shall be in conformance with the requirements of Test Methods E 18 and E 10, respectively.

4.1.2 Readings when taken on the bearing face shall be halfway between the major diameter of the thread and one corner. The reported hardness shall be the average of two hardness readings located 180° apart. The readings when taken on the wrench flats shall be one third of the distance from a corner to the center of the wrench face. The reported hardness shall be the average of two readings located from opposite corners.

4.1.3 For the purpose of arbitration or for nuts too large for full size testing, where hardness alone shall determine acceptance (see 4.1.4), the following shall apply.

4.1.3.1 Sample nuts shall be sectioned laterally at approximately one half ($\frac{1}{2}$) of the nut height. Such samples need not be threaded, but shall be part of the manufacturing lot that was formed (in the case of heat-treated nuts, formed and heat-treated) with the product to be shipped. The preparation of the sample shall be in accordance with 4.1.1 above. All readings shall be conducted on a Rockwell Hardness Testing machine. For standard hex, heavy hex and square nuts, the half of the nut not to be tested may be discarded. For special nut configurations both sections shall be identified and made available to the purchaser, if specified on the purchase order or inquiry.

4.1.3.2 Nonheat-Treated Nuts (see Fig. 11)—Two readings shall be taken 180° apart at the core (halfway between the major diameter if threaded, or blank hole if not threaded) and a corner of the nut. The reported hardness shall be the average of the two readings, and in addition both readings shall be within the hardness values listed in the product specification.

4.1.3.3 Heat-Treated Nuts (See Fig. 12)—Two sets of three readings 180° apart shall be taken. The three readings shall be taken across the section of the nut at the following positions:

- **Position 1**—As close to the major diameter, as possible, if threaded, or hole side wall if the nut is black, but no closer than 2 1/2 times the indent diameter.
- **Position 2**—At the core (halfway between the major diameter, if threaded, or hole side wall, if blank) and a corner of the nut.
- **Position 3**—As close to the corner of the nut as possible, but no closer than 2 1/2 times the indent diameter.

4.1.3.4 The reported hardness shall be the average of all six readings. In addition all readings shall be within hardness values listed in the product specification.

4.1.4 Nuts exhibiting a proofload in excess of 160 000 lb may be considered, at the option of the manufacturer, as too large for full-size testing. Full-size testing is recommended whenever possible.

4.1.5 For nuts on which hardness and proof load tests are performed, acceptance based on proof load requirements shall take precedence in the event of controversy with hardness tests.

4.2 Proof Load Test—Assemble the nut to be tested on a hardened threaded mandrel 4.2.2) or a test bolt (4.2.1) as shown in Fig. 13(a) Tension Method or Fig. 13(b) Compression Method. The hardened test mandrel and the tension method shown in Fig. 13(a) shall be mandatory as a reference.
if arbitration is necessary. Apply the specified proof load for the nut against the nut. The nut shall resist this load without stripping or rupture, and shall be removable from the test bolt or mandrel by the fingers after the load is released. Occasionally it may be necessary to use a manual wrench or other means to start the nut in motion. Use of such means is permissible, provided the nut is removable by the fingers following the initial loosening of not more than one-half turn of the nut. If the threads of the mandrel or test bolt are damaged during the test, discard the test.

4.2.1 The test fastener shall be appropriate to the standard specified for the nut being tested and shall have a yield strength in excess of the specified proof load of the nut being tested.

4.2.2 Mandrels shall have a hardness of 45 HRC minimum; the mandrel shall have threads conforming to the same standards as those specified for the nut being tested, except that the maximum major diameter shall be the specified minimum major diameter for class 4H6H threads and the maximum major diameter plus 0.25 times the major diameter tolerance of class 4H6H threads.

4.2.3 The proof load shall be determined at a free running cross head not exceeding 25 mm/minute and shall be held at load for 10 s minimum.

4.3 Cone Proof Load Tests—Perform this test using a conical washer and threaded mandrel (as illustrated in Fig. 14) to determine the influence of surface discontinuities (forging cracks and seams) on the load-carrying ability of hardened steel nuts through 36 mm in diameter by introducing a simultaneous dilation and stripping action of the nut. The mandrel shall conform to the requirements of 4.2.2. The conical washer shall have a hardness of 57 HRC minimum and a hole diameter of the mandrel +0.05 mm and −0.00 mm. The contact point of the cone shall be sharp for nut sizes 12 mm or less. For sizes greater than 12 mm the point shall be flat and 0.38 mm ± 0.03 mm in width. Assemble the nut and the conical washer on the mandrel, and apply the cone proof load for the nut against the nut. The speed of testing as determined with a free-running cross head shall be a maximum of 3 mm/mm. Apply the proof load for 10 s. The proof load of the nut is computed as follows:

$$CPL = (1 - 0.012D)f 	imes A_s 	imes 0.001$$ (5)
where:
\(CPL\) = cone proof load, kN,
\(D\) = nominal diameter of nut, mm,
\(f\) = specified proof stress of nut, MPa,
\(A_s\) = tensile stress area of nut, mm\(^2\),
\[A_s = 0.7854 \left[D - (0.9382P)^2\right],\]
and
\(P\) = thread pitch, mm.

To meet the requirements of the cone proof load test, the nut shall support its specified cone proof load without stripping or rupture.

5. Test Methods for Washers and Direct Tension
Indicators

5.1 General Requirements:

5.1.1 All tests shall be conducted on a Rockwell hardness tester.

5.1.2 Use of a 6 mm (¼ in.) or smaller spot anvil shall be used for hardness testing of washers and direct tension indicators.

5.1.3 Readings are not to be taken on or near product markings.

5.1.4 Preparation of test specimens and the performance of hardness tests shall be performed in accordance with Test Methods E 18.

5.1.5 For arbitration purposes, a minimum of two readings 180° apart on at least one face shall be taken. (See Fig. 15).

5.1.6 All readings shall be within the hardness values listed in the product specification, and the average of all readings shall be considered as the hardness of the product.

5.1.7 An initial reading may be used to establish that the hardness testing equipment is properly set up and that the correct scale is being used. Such readings are not used to determine conformance.

5.2 Through Hardened Washers:

5.2.1 Surface Hardness—Take hardness readings on a smooth flat portion of the washer, prepared by light grinding or polishing as necessary.

5.2.2 Core Hardness—Take hardness readings on a smooth flat portion of the washer, prepared by light grinding or polishing such that readings are taken at a minimum depth of 0.38 mm (0.015 in.) from the original surface.

5.3 Carburized Washers:

5.3.1 Surface Hardness—Take hardness readings on a smooth flat portion of the washer, using a method which prevents penetration into the core material.

5.3.2 Core Hardness—Take hardness readings on a smooth flat portion of the washer, prepared by light grinding or polishing such that readings are taken at a depth greater than the depth of case.

5.3.3 Depth of Case—Measurements of case depth shall be taken at a cross section through the rim of the washer, having been ground and etched to define the case area.

5.4 Stainless Steel and Nonferrous Washers:

5.4.1 Surface Hardness—Take hardness readings on a smooth flat portion of the washer.

5.4.2 Core Hardness—Take hardness readings on a smooth flat portion of the washer, prepared by light grinding or
polishing such that readings are taken at a minimum depth of 0.38 mm (0.015 in.) from the original surface.

5.5 Direct Tension Indicators:

5.5.1 Surface Hardness—Take hardness readings on a smooth flat portion of the DTI, at a point approximately midway between the protrusion (top side) or pocket (bottom side) and the outside diameter. Prepare the DTI by light grinding or polishing as necessary.

5.5.2 Core Hardness—Take hardness readings on a smooth flat portion of the DTI, at a point approximately midway between the protrusion (top side) or pocket (bottom side) and the outside diameter. Prepare the DTI by light grinding or polishing such that readings are taken at a minimum depth of 0.38 mm (0.015 in.) from the original surface.

6. Rivets

6.1 Product Hardness—Determine hardness at the mid-radius of a transverse section of the product taken at a distance of one diameter from the point end of the rivet. Use either Brinell or Rockwell hardness tests, and measure as described in 3.1.

7. Test for Embrittlement of Metallic Coated Externally Threaded Fasteners

7.1 This is one test method for determining if embrittlement exists in a metallic coated externally threaded fastener covered by the product specifications of ASTM Committee F16.

7.2 The test fastener shall be installed in a test fixture (see Note 1 in Fig. 16) with the head positioned against the wedge, assembled with a nut, and tensioned (by means of the nut only) by any means capable of measuring tensile load. The torque method described in 7.3 is one such method. The test samples shall be tensioned to 75 % of their specified minimum ultimate tensile strength. For studs with different thread pitches on either end, the finer thread pitch end shall be assembled with a nut and tested as the head end of the fastener.

7.2.1 The assembly shall remain in this tightened state for not less than 48 h, after which the test fastener shall be visually examined for embrittlement-induced failure, such as missing head.

7.2.2 The joint shall then be disassembled and the test fastener visually examined using a minimum of 20 power magnification for evidence of embrittlement failure, such as transverse cracks in the shank, threads or at the junction of head to shank.

7.2.3 For disassembly, if the torque method of tightening is used, torque shall be applied in the ON direction until the nut rotates a noticeable amount. The retightening torque with the nut in motion shall be measured and shall be no less than 90 % of the initial tightening torque.

7.2.4 If a direct tension method of tightening is used, then the loss of clamping strength (in kilograms) over the test period shall be no more than 10 % of the initial clamping load.

7.3 The test fixture shall comprise a hardened wedge (see 7.3.1), a plate(s) (see 7.3.2), and a hardened washer (see 7.3.3). (See Fig. 16).

7.3.1 The wedge shall have an angle as specified in Table 4. Other dimensions and properties shall be in conformance with hardened wedges described in 3.5.1.

7.3.2 The plate(s) shall be steel and have a thickness such that, after installation and tightening, a minimum of three full threads of the test fastener will be in the grip. The hole in the plate(s) shall be as close to the major diameter of the fastener being tested as practical but not greater than the hole in the hardened washer (see 7.2.3).

7.3.3 The hardened washer shall be in conformance with Specification F 436M.

7.4 If the torque method of tightening is used, the tightening torque shall be determined using a load-measuring device.
capable of measuring the actual tension induced in a fastener as the fastener is tightened. Three fasteners from the test lot shall be selected at random. Each shall be assembled into the load-measuring device, mated with a nut, and the nut tightened until a load equal to 75% of the specified minimum ultimate tensile strength of the fastener is induced. The torque required to induce this load shall be measured and the arithmetic average of the three measured torques shall be the tightening torque. The surface against which the nut is torqued should be similar in hardness and finish to that of the test fixture (see Fig. 16) and use of a hardened washer (see 7.3.3) is recommended.

7.5 To meet the requirements of this test the fastener shall show no evidence of embrittlement failure when visually examined and the retightening torque shall not be less than 90% of the initial tightening torque.

Note 10—The nature of this test method is such that a fastener will either pass or fail as a result of being subjected to the test conditions. The qualitative nature of the test does not provide information on how close or how far a fastener is from failure. This test method is to be used for embrittlement testing on a production scale and is not to be used for analytical purposes. Test Method F 1624 can be used as an analytical method to test fastener products in cases of uncertainty, or where quantitative or analytical data are required. Test Method F 1624 is not suited for embrittlement testing on a production scale due to the time and costs associated with performing the test.

ANNEX

(Mandatory Information)

A1. TEST METHOD FOR MEASURING COMPRESSION LOADS (ALL FINISHES) ON DIRECT TENSION INDICATORS COVERED BY TEST METHOD F 959M

A1.1 Testing Apparatus

A1.1.1 Test the direct tension indicators in an apparatus described herein that is capable of determining their performance characteristics with sufficient accuracy.

A1.1.2 Testing apparatus shall include a compression loading system, top and bottom bearing blocks, and support blocks that allow each direct tension indicator to be calibrated using a direct reading gage.

A1.1.3 The testing apparatus shall conform to the requirements of Practices E 4. The loads used in determining compressive loads shall be within the verified loading range of the testing machine in accordance with Practices E 4.

A1.1.4 The direct reading gage of the testing apparatus shall be capable of measuring the gap variation to within 0.0125 mm.

Note A1.1—Because of acceptable variations in bolt dimensions and coating characteristics, bolts cannot be used as a means of gaging the direct tension indicator minimum and maximum performance.

A1.2 Compression Loading System

A1.2.1 The compression loading system shall transmit a compressive load axially from the testing apparatus to the direct tension indicator. The bottom bearing block of the loading system must be able to accept the cylindrical protrusions of the direct tension indicator support blocks.

A1.2.2 Maintain the compression loading system in good operating condition and use only in the proper loading range.

A1.3 Support Blocks

A1.3.1 Support blocks shall be grooved on one side so that the direct reading gage can be zeroed without compressing the direct tension indicator protrusions. (See Fig. A1.1.) Thus, the exact thickness of the direct tension indicator being tested is taken into account, and the flat surface of the side of the direct tension indicator having protrusions is made to relate exactly to the zero point of the gage that shall react on the center of the direct tension indicator support block.

A1.3.2 Support blocks shall have a minimum Rockwell hardness of 50 HRC.

A1.3.3 Support blocks shall conform to the dimensions shown in Fig. A1.2.

A1.3.4 The surfaces of support blocks shall be parallel to within 0.005 mm across the diameter of the support block.

A1.4 Bearing Blocks

A1.4.1 The upper bearing block shall have a minimum diameter of 75 mm.

A1.4.2 Bearing blocks shall have a minimum Rockwell hardness of 50 HRC.

A1.4.3 The upper and bottom bearing block surfaces shall be parallel to within 0.0125 mm across the width of the support block.

A1.5 Calibration

A1.5.1 Calibrate the testing apparatus and its direct reading gage at least once per year.
A1.5.2 Retain the calibrated test data.

A1.6 Test Procedure

A1.6.1 Select the support block corresponding to the size and type of direct tension indicator to be tested.

A1.6.2 The direct reading gage spindle shall be in contact with the center of the direct tension indicator support block during the test. (See Fig. A1.3.)

A1.6.3 Zero Direct Reading Gage—Place the direct tension indicator, with protrusions facing down, into the grooves of the support block. Apply compression load equal to the minimum required load for the size and type of direct tension indicator being tested. Set the direct reading gage at zero. Release the load and remove the direct tension indicator. See Step 1 of Fig. A1.3.

A1.6.4 Invert the support block so that Side A with the groove is facing down.

A1.6.5 Measure Compression Load:

A1.6.5.1 Place the flat surface of the direct tension indicator against Side B of the support block with protrusions facing up.

Note 1—Height of boss = 2.16 mm +0/−0.0125 mm with no more than 0.005 mm difference between side “A” and side “B”.

**FIG. A1.2 Support Block Dimensions**

<table>
<thead>
<tr>
<th>Size</th>
<th>C mm</th>
<th>E mm</th>
<th>F mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>M16</td>
<td>15.5</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>M20</td>
<td>19.5</td>
<td>19</td>
<td>34</td>
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<td>M22</td>
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<td>M30</td>
<td>29.5</td>
<td>29</td>
<td>53.5</td>
</tr>
<tr>
<td>M36</td>
<td>35.5</td>
<td>35</td>
<td>63</td>
</tr>
</tbody>
</table>
Apply compression load until the gage reading is the test gap specified in this specification for the size, type, and surface condition of the direct tension indicator being tested. See Step 2 of Fig. A1.3.

A1.6.5.2 Apply the compression load at a rate such that the direct tension indicator is compressed within 30 s from the time the compression load is first applied until the proper gap is achieved.

A1.6.6 Read and Record—Read the compression load within 5 s of reaching the test gap and record the results.
Standard Test Methods for Nails

This standard is issued under the fixed designation F 680; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods cover procedures for the testing of nails. The test or tests selected, and the requirements for compliance, will be as specified in the applicable product standard. Performance tests for nail withdrawal and lateral load capability are not included as they are covered by Test Methods D 1761.

1.2 The tests described are as follows:

<table>
<thead>
<tr>
<th>Section</th>
<th>Dimensional tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Tension test</td>
</tr>
<tr>
<td>6</td>
<td>Conventional bend test</td>
</tr>
<tr>
<td>7</td>
<td>Impact bend test</td>
</tr>
<tr>
<td>8</td>
<td>Rockwell hardness test</td>
</tr>
<tr>
<td>9</td>
<td>Coating weight test</td>
</tr>
<tr>
<td>10</td>
<td>Coating adherence test for zinc-coated nails</td>
</tr>
</tbody>
</table>

1.3 This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values in parentheses are provided for information purposes only.

2. Referenced Documents

2.1 ASTM Standards:

- A 90/A 90M Test Method for Weight [Mass] of Coating on Iron or Steel Articles with Zinc or Zinc-Alloy Coatings
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 428/A 428M Test Method for Weight [Mass] of Coating on Aluminum-Coated Iron or Steel Articles
- D 1761 Test Methods for Mechanical Fasteners in Wood
- E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
- F 547 Terminology of Nails for Use with Wood and Wood-Base Materials
- F 592 Terminology of Collated and Cohered Fasteners and Their Application Tools

3. Terminology

3.1 Definitions—For definitions of terms used in this test method, refer to Terminology F 547 and F 592.

4. Significance and Use

4.1 When specified, the tests selected for application shall be performed to assure conformance with requirements stipulated in the product specification.

5. Dimensional Tests

5.1 Dimensions to be evaluated include, but shall not be limited to length, stock diameter, diameter or major dimensions of head, straightness, head concentricity to shank, and length of point. For mechanically deformed nails, angle, depth, and configuration of deformations shall be measured as specified. Other dimensional characteristics shall be measured when required. Any suitable measuring means may be applied.

6. Tension Test

6.1 Nails are not subject to tension testing. However, wire used to make the nails may be tested as required by prior agreement or to affect mill product control. The testing of wire is covered in the general section of Test Methods A 370 and Supplement IV, Round Wire Products.

7. Conventional Bend Test

7.1 This test is used as a means of testing the ductility of certain types of nails or of the wires used in the manufacture of nails. The angle of bend and the mandrel diameter will be specified in the product specification. The cold bending shall be performed by any hand or power device that will deform the sample closely about a mandrel of specified diameter through the required angle without causing damage to the nail surface. The sample shall be considered to have failed if fracture occurs prior to attainment of the required minimum bend angle. Unless otherwise specified, the conventional bend test shall not
be applied to annularly threaded nails or to the region of a nail exhibiting gripper marks.

8. Impact Bend Test

8.1 The impact test is primarily applicable to the testing of pallet nails to assess their suitability for that application. The testing device is shown in Fig. 1 and its operation is described in Annex A1. For any given diameter, the data from this test can be correlated with Rockwell hardness used to specify the mechanical properties of the nail. The impact bend test is intended as a convenient test that may be used in manufacturing and consumer quality monitoring of mechanical properties. However, in the case of dispute, the Rockwell hardness test, supplemented by the conventional bend test, will be considered the governing test.

9. Rockwell Hardness Test

9.1 This test is used to measure the hardness of heat-treated nails. Prepare flat surfaces by grinding or filing. Take care not to alter the tempered hardness of the nail during preparation of the flats. The width of the prepared flat shall be sufficient to prevent edge bulge adjacent to each hardness impression. The thickness at the test section shall be sufficient to avoid a bulge or other visible markings on the surface opposite to the impression. Hardness can be determined using a shank having prepared parallel surfaces. Determine the hardness in accordance with Test Methods E 18. Usually three readings are made on a nail and these readings are averaged for the final result.

9.2 An alternate method for determining Rockwell hardness is to cut the nail off about ½ in. (13 mm) from the head. Grind the top of the head to remove scale and obtain a flat surface. Grind the transversely cut end flat, using proper precautions not to alter the tempered hardness of the nail. Place the sample head down on the anvil of the hardness testing machine and determine the hardness on the transverse section.

10. Coating Weight Test

10.1 This test deals with zinc, aluminum, and copper-clad coatings only and does not deal with other metallic coatings such as cadmium.

10.2 Cut the heads and points from samples of zinc-coated or aluminum-coated nails selected for testing. Take a sufficient number of such specimens to provide a total length over 12 in. 

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**Fig. 1** A Typical Impact Bend Tester for the Impact Bend Testing of Nails

*Note:* This device is available from The National Wooden Pallet and Container Assn., 1625 Massachusetts Ave., Washington, DC 20036
(300 mm), preferably about 24 in. (600 mm). Since the density of the steel is known (0.2836 lb/in.³ (0.1276 kg/m³)), it is not necessary to use a specific total length of specimens.

10.3 Determine the weight of zinc coating in accordance with Test Method A 90.

10.4 Determine the weight of aluminum coating in accordance with Test Method A 428.

10.5 Determine the thickness of coating of copper-clad nails by one of the following three methods:

10.5.1 Accurately measuring the diameter of the wire before and after removing the cladding by any suitable means.

10.5.2 Cutting off the wire, grinding one end smooth, etching the exposed cross section to differentiate between core and cladding, and measuring under suitable magnification.

10.5.3 Using electrical indicating instruments.

10.6 Calculate the weight of the copper cladding from the thickness as measured above or determine the weight of the cladding by chemically stripping the copper and accurately weighing the wire sample before and after stripping.

11. Coating Adherence Test for Zinc-Coated Nails

11.1 Determine the adherence of the zinc coating to the surface of the base metal by cutting or prying with the point of a stout knife, applied with considerable pressure in a manner tending to remove a portion of the coating. The adherence shall be considered inadequate if the coating flakes off in the form of a layer or skin so as to expose the base metal in advance of the knife point. Testing carried out at edges or corners (points of lowest coating adherence) shall not be used to determine adherence of coating. Likewise, removal of small particles of the coating by paring or whittling shall not be used to determine failure.

12. Precision and Bias

12.1 The precision and bias of these tests have not been determined at this time.

ANNEX

(Mandatory Information)

A1. OPERATION OF THE IMPACT BEND TESTER (FIG. NO. 1)

A1.1 Scope—The test is applicable to nails with shank diameters of 0.106 in. (2.7 mm) to 0.135 in. (3.4 mm) and lengths of 1½ in. (38 mm) to 3 in. (76 mm) and with or without deformations.

A1.2 Hold the nail to be tested in a chuck in such a way that it cantilevers 1½ in. (12 mm) at an angle of 80° to the vertical. Hit its head after the free-fall drop of a 3.50-lb (1.58-kg) weight from a 15⁷/₁₆ in. (392 mm) height, thereby applying 54.0 in.·lbf (6.1-J potential or 4.52-J kinetic) energy to the head of the inclined nail. As a result of this impacting, soft nails are bent readily without breaking and non-ductile nails fail abruptly partially or completely while being bent only a few degrees. The test includes recording the bend angle of the tested nail as well as the number and type of failure, if any.

A1.3 The impact bend test device, shown in Fig. 1, shall consist of a 0.750-in. (19.0-mm) diameter shaft, along which the 3.50-lb (1.58-kg) drop weight slides to hit the head of the nail. A protractor shall be used to measure the angle of the tested nail.

A1.4 Measure the dimensions of the nails prior to testing. Replace chuck inserts with worn edges with new ones. Position the specimen properly between the chuck inserts in such a way that the specimen protrudes 1½ in. (12 mm) from the inserts. Tighten the chuck securely, to prevent the displacement of the nail during application of the impact load, and release the drop weight. Record the type of failure, if any, and the bend angle for each nail and determine the average bend angle for the nails tested.
Standard Specification for Stainless Steel Metric Bolts, Screws, and Studs

This standard is issued under the fixed designation F 738M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers the chemical and mechanical requirements for stainless steel metric bolts, screws, and studs with nominal thread diameters M1.6 through M36 and is intended for use in engineering applications requiring general corrosion resistance.

1.2 Eight groups of stainless steel alloys are covered, including three austenitic (Grades A1, A2, and A4), one ferritic (Grade F1), three martensitic (Grades C1, C3, and C4), and one precipitation hardening (Grade P1).

1.3 Twenty property classes are covered, including nine austenitic, two ferritic, eight martensitic, and one precipitation hardening. The property classes with the permissible alloys for each are listed in Table 1.

1.4 This specification is based in concept and content on ISO 3506. The chemical and mechanical requirements specified for all property classes, except as given in 1.4.1, are essentially identical with classes of the same designation in ISO 3506.

1.4.1 This specification includes all of the property classes covered in ISO 3506. Additionally, it includes property classes A1-70, A2-70, A4-70, A1-80, A2-80, and A4-80 for products with nominal thread diameters larger than M20; and four non-ISO property classes, C1-110, C4-110, C3-120; and P1-90.

1.5 Supplementary requirements of an optional nature are provided, applicable only when agreed upon between the manufacturer and the purchaser at the time of the inquiry and order.

1.6 Suitable nuts for use with bolts, screws, and studs included in this specification are covered by Specification F 836M.

1.7 The following safety hazards caveat pertains only to the test method described in this specification. This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
A 276 Specification for Stainless Steel Bars and Shapes
A 342/A 342M Test Methods for Permeability of Feebly Magnetic Materials
A 380 Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
A 484/A 484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings
A 493 Specification for Stainless Steel Wire and Wire Rods for Cold Heading and Cold Forging
A 555/A 555M Specification for General Requirements for Stainless Steel Wire and Wire Rods
A 564/A564M Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes
A 582/A 582M Specification for Free-Machining Stainless Steel Bars
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
D 3951 Practice for Commercial Packaging
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys
F 606M Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets [Metric]
F 836M Specification for Style 1 Stainless Steel Metric Nuts

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1 This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.04 on Nonferrous Fasteners.

2. Classification

3.1 The designation of each property class is composed of three parts: a letter, followed by a single digit, followed by either two or three digits.

3.1.1 The letter indicates the general composition type of stainless steel as follows:

3.1.1.1 A for austenitic steels,
3.1.1.2 F for ferritic steels,
3.1.1.3 C for martensitic steels, and
3.1.1.4 P for precipitation-hardening steel.

3.1.2 The first digit (1, 2, 3, or 4) indicates the alloy group. The permissible alloys within each group are given in Table 1.

3.1.3 The last two or three digits (50, 70, 110, etc.) indicate 10% of the specified minimum tensile strength of the property class.

3.1.4 For example, Class A1-50 is an austenitic steel of any one of six permitted alloys, and the manufactured fastener has a minimum tensile strength of 500 MPa.

### TABLE 1 Property Classes of Stainless Steel Bolts, Screws, and Studs

<table>
<thead>
<tr>
<th>Property Class</th>
<th>Permissible Alloys</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1-50</td>
<td>304, 304L, 305&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>A1-70</td>
<td>384, 18-9LW, 302HQ</td>
</tr>
<tr>
<td>A1-80</td>
<td></td>
</tr>
<tr>
<td>A2-50</td>
<td>321, 347</td>
</tr>
<tr>
<td>A2-70</td>
<td></td>
</tr>
<tr>
<td>A2-80</td>
<td></td>
</tr>
<tr>
<td>A4-50</td>
<td>316, 316L</td>
</tr>
<tr>
<td>A4-70</td>
<td></td>
</tr>
<tr>
<td>A4-80</td>
<td></td>
</tr>
<tr>
<td>F1-45</td>
<td>430&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>F1-60</td>
<td></td>
</tr>
<tr>
<td>C1-50</td>
<td>410</td>
</tr>
<tr>
<td>C1-70</td>
<td></td>
</tr>
<tr>
<td>C1-110</td>
<td></td>
</tr>
<tr>
<td>C3-80</td>
<td>431</td>
</tr>
<tr>
<td>C3-120</td>
<td></td>
</tr>
<tr>
<td>C4-50</td>
<td>416, 416Se</td>
</tr>
<tr>
<td>C4-70</td>
<td></td>
</tr>
<tr>
<td>C4-110</td>
<td></td>
</tr>
<tr>
<td>P1-90</td>
<td>630</td>
</tr>
</tbody>
</table>

<sup>a</sup> When approved by the purchaser, Alloys 303, 303Se, or XM1 may be furnished.

<sup>3</sup> When approved by the purchaser, Alloy 430F may be furnished.

5. Materials and Manufacture

5.1 Materials:

5.1.1 Specifications A 276, A 493, A 564/A 564M, and A 582/A 582M are noted for information only as suitable sources of material for the manufacture of bolts, hex cap screws, and studs to this specification.

5.2 Manufacture:

5.2.1 Forming—Unless otherwise specified, fasteners shall be cold-formed, hot-formed, or machined, at the option of the manufacturer.

5.2.2 Threads—Unless otherwise specified, threads shall be rolled or cut at the option of the manufacturer.

5.2.3 Condition—Fasteners shall be furnished in the condition specified for the property class in Table 2. If other conditions are required, the condition and resultant mechanical properties shall be as agreed upon between the manufacturer and the purchaser.

5.2.4 Surface Finish—Fasteners shall have a surface finish
produced in accordance with Practice A 380.

5.2.5 Protective Finishes—Unless otherwise specified, fasteners shall be furnished without an additive chemical or metallic finish.

6. Heat Treatment

6.1 Austenitic Alloys, Grades A1, A2, and A4

6.1.1 When Condition AF is specified, the fasteners, following manufacture, shall be annealed by heating to 1040 ± 30°C, at which time the chromium carbide will go into solution. The fasteners shall be held for a sufficient time and then cooled at a rate sufficient to prevent precipitation of the carbide and to provide the properties specified in Table 2.
6.1.2 When Condition CW is specified, the austenitic alloy shall be annealed as specified in 6.1.1, generally by the raw material manufacturer, and then cold-worked to develop the properties specified in Table 2.

6.2 Ferritic Alloys, Grade F1

6.2.1 When Condition AF is specified, the ferritic alloy shall be heated to a temperature of 790 ± 30°C, held for an appropriate time, and then air-cooled to provide the properties specified in Table 2.

6.2.2 When Condition CW is specified, the ferritic alloy shall be annealed as specified in 6.2.1, generally by the raw material manufacturer and then cold-worked to develop the properties specified in Table 2.

6.3 Martensitic Alloys, Grades C1, C3, and C4

6.3.1 When Condition A is specified, the fasteners, following manufacture, shall be annealed to provide the properties specified in Table 2.

6.3.2 When Condition H is specified, the fasteners shall be hardened and tempered by heating to 1010 ± 30°C sufficient for austenitization, holding for at least ½ h, rapid air- or oil-quenching, reheating to 565°C minimum, and holding for at least 1 h and then air-cooling to provide the properties specified in Table 2.

6.3.3 When Condition HT is specified, the fasteners shall be hardened and tempered by heating to 1010 ± 30°C sufficient for austenitization, holding for at least ½ h, rapid air- or oil-quenching, reheating to 275°C minimum, holding for at least 1 h, and then air-cooling to provide the properties specified in Table 2.

6.4 Precipitation-Hardening Alloy, Grade P1—When Condition AH is specified, the fasteners shall be solution-annealed and aged by heating to 1040 ± 15°C, holding for at least ½ h, rapid air- or oil-quenching to 27°C maximum, reheating to 620 ± 10°C minimum, holding for 4 h, and then air-cooling to provide the properties specified in Table 2.

7. Chemical Composition

7.1 It is the intent of this specification that fasteners shall be ordered by property class.

7.2 Unless otherwise specified in the inquiry and purchase order (see Supplementary Requirement S2), when two or more alloys are permitted for fasteners of a specified property class, the choice of alloy to be used shall be that of the fastener manufacturer as determined by his fastener fabrication methods and material availability. The specific alloy used by the manufacturer shall be clearly identified on any certification required in the purchase order and shall have a chemical composition conforming to the limits specified in Table 3.

7.2.1 When the purchaser specifies that a specific alloy be used, the alloy shall have a chemical composition conforming to the limits specified in Table 3.

7.3 Product analysis may be made by the purchaser from finished fasteners representing each lot. The chemical composition thus determined shall conform to the limits specified in Table 3.

### TABLE 3 Chemical Requirements

<table>
<thead>
<tr>
<th>Alloy Group</th>
<th>Alloy Designation</th>
<th>Composition, % maximum except as shown</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austenitic Alloys</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>303 S30300</td>
<td>0.15</td>
<td>2.00</td>
</tr>
<tr>
<td>A1</td>
<td>303Se S30323</td>
<td>0.15</td>
<td>2.00</td>
</tr>
<tr>
<td>A1</td>
<td>304 S30400</td>
<td>0.08</td>
<td>2.00</td>
</tr>
<tr>
<td>A1</td>
<td>304L S30403</td>
<td>0.03</td>
<td>2.00</td>
</tr>
<tr>
<td>A1</td>
<td>305 S30500</td>
<td>0.12</td>
<td>2.00</td>
</tr>
<tr>
<td>A1</td>
<td>384 S38400</td>
<td>0.08</td>
<td>2.00</td>
</tr>
<tr>
<td>A1</td>
<td>XM1 S20300</td>
<td>0.08</td>
<td>5.0 to 6.5</td>
</tr>
<tr>
<td>A1</td>
<td>18–9LW S30430</td>
<td>0.10</td>
<td>2.00</td>
</tr>
<tr>
<td>A1</td>
<td>302HQ S30433</td>
<td>0.03</td>
<td>2.00</td>
</tr>
<tr>
<td>Ferritic Alloys</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>430 S43000</td>
<td>0.12</td>
<td>1.00</td>
</tr>
<tr>
<td>F1</td>
<td>430F S43020</td>
<td>0.12</td>
<td>1.25</td>
</tr>
<tr>
<td>Martensitic Alloys</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>410 S41000</td>
<td>0.15</td>
<td>1.00</td>
</tr>
<tr>
<td>C4</td>
<td>416 S41600</td>
<td>0.15</td>
<td>1.25</td>
</tr>
<tr>
<td>C4</td>
<td>416Se S41623</td>
<td>0.15</td>
<td>1.25</td>
</tr>
<tr>
<td>C3</td>
<td>431 S43100</td>
<td>0.20</td>
<td>1.00</td>
</tr>
</tbody>
</table>

<sup>a</sup> At manufacturer’s option, determined only when intentionally added.
Table 3 for the specific alloy within the product analysis tolerances specified in Specification A 555/A 555M.

7.3.1 In the event of discrepancy, a referee analysis of samples for each lot shall be made in accordance with 9.3.1.

8. Mechanical Properties

8.1 Bolts, screws, and studs shall be tested in accordance with the mechanical testing requirements for the applicable product type, property class, nominal thread diameter, length, and specified minimum tensile strength as specified in Table 4, and shall meet the mechanical requirements specified for that product in Tables 2-6.

8.2 For products on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence over low hardness readings.

9. Number of Tests and Retests

9.1 The requirements of this specification shall be met in continuous mass production for stock and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily necessary.

9.1.1 Individual heats of steel are not identified in the finished product. When specified in the purchase order that the heat number shall be identified for the products in an individual shipment, the manufacturer shall control the product by heat analysis and additionally shall conduct the testing program specified in 9.3.1.

### TABLE 4 Mechanical Testing Requirements for Bolts, Screws, and Studs

<table>
<thead>
<tr>
<th>Item</th>
<th>Product</th>
<th>Nominal Thread Diameter</th>
<th>Property Class</th>
<th>Specified Tensile Strength of Product, min, kn</th>
<th>Length(^1) of Product</th>
<th>Product Hardness</th>
<th>Tests Conducted Using Full-Size Products(^2)</th>
<th>Tests Conducted Using Machined Test Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tensile Strength</td>
<td>Axial Tensile Strength</td>
</tr>
<tr>
<td>1</td>
<td>Short-length bolts, screws, studs</td>
<td>all</td>
<td>all</td>
<td>all</td>
<td>less than X</td>
<td>M</td>
<td>M</td>
<td>...</td>
</tr>
<tr>
<td>2</td>
<td>Special-head bolts and screws</td>
<td>all</td>
<td>all</td>
<td>all</td>
<td>...</td>
<td>M</td>
<td>M</td>
<td>...</td>
</tr>
<tr>
<td>3</td>
<td>Screws and studs, except items 1, 2</td>
<td>M1.5-M5</td>
<td>A1, A2, A4</td>
<td>all</td>
<td>X and longer</td>
<td>M</td>
<td>M</td>
<td>...</td>
</tr>
<tr>
<td>4</td>
<td>Screws and studs, except items 1, 2, 3</td>
<td>M1.6-M5</td>
<td>all</td>
<td>all</td>
<td>X and longer</td>
<td>M</td>
<td>M</td>
<td>...</td>
</tr>
<tr>
<td>5</td>
<td>Bolts and screws with hex or hex flange heads, except items 1, 2</td>
<td>M6-M36</td>
<td>all</td>
<td>450 and less</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tensile Strength</td>
<td>Axial Tensile Strength</td>
</tr>
<tr>
<td>6</td>
<td>All other bolts and screws, except items 1 through 5</td>
<td>M5-M36</td>
<td>all</td>
<td>over 450 and less</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>7</td>
<td>All studs, except Items 1, 2, 3, 4</td>
<td>M6-M36</td>
<td>all</td>
<td>over 450 and less</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

\(^1\)M" denotes a mandatory test. For each product, all mandatory tests shall be performed. In addition, either all tests denoted "FS" (which apply to full-size products) or all tests denoted "MS" (which apply to machined test specimens) shall be performed. In case of arbitration is necessary, "FS" tests shall be performed. Leaders ( . . . ) denote tests that are not required.

\(^2\)For values of length X see Table 6.

\(^\star\)Acceptance values for these tests are contained in Table 5.

\(^\star\)Special-head bolts and screws are those with special configuration or drilled heads which are weaker than the threaded section.
9.2 When specified in the purchase order, the manufacturer shall furnish a test report certified to be the last complete set of chemical analysis and mechanical tests for each stock size in each shipment.

9.3 When the purchaser requires that additional tests be performed by the manufacturer to determine that the properties of products in an individual shipment are within specified limits, the purchaser shall specify the testing requirements, including the sampling plan and basis of acceptance, in the inquiry and purchase order.

9.3.1 When the purchaser does not specify the sampling plan and basis of acceptance the following shall apply:

9.3.1.1 The lot, for purposes of selecting samples, shall consist of all products offered for inspection and testing, at one time, that are the same type, style, nominal diameter, thread pitch, nominal length, material (alloy), property class, and surface finish.

9.3.1.2 From each lot, samples shall be selected at random and tested for each requirement in accordance with the following plan:

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Tests</th>
<th>Acceptance Number</th>
<th>Rejection Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and less</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>801 to 8000</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>8001 to 22 000</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Over 22 000</td>
<td>5</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

9.3.1.3 If the failure of a test specimen is due to improper preparation of the specimen or to incorrect testing technique, the specimen shall be discarded and another test specimen substituted.

### TABLE 5 Yield and Tensile Strength Values for Full-Size Fasteners, kN

<table>
<thead>
<tr>
<th>Nominal Size and Thread Pitch</th>
<th>Stress Area, ( \text{mm}^2 )</th>
<th>Yield or Tensile Stress, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>210</td>
</tr>
<tr>
<td>M1.6 x 0.35</td>
<td>1.27</td>
<td>0.57</td>
</tr>
<tr>
<td>M2 x 0.4</td>
<td>2.07</td>
<td>0.93</td>
</tr>
<tr>
<td>M2.5 x 0.45</td>
<td>3.39</td>
<td>1.52</td>
</tr>
<tr>
<td>M3 x 0.5</td>
<td>5.03</td>
<td>2.26</td>
</tr>
<tr>
<td>M4 x 0.7</td>
<td>8.78</td>
<td>3.95</td>
</tr>
<tr>
<td>M5 x 0.8</td>
<td>14.2</td>
<td>6.39</td>
</tr>
<tr>
<td>M6 x 1.25</td>
<td>20.1</td>
<td>8.04</td>
</tr>
<tr>
<td>M8 x 1.5</td>
<td>36.6</td>
<td>14.6</td>
</tr>
<tr>
<td>M10 x 1.5</td>
<td>58.0</td>
<td>23.2</td>
</tr>
<tr>
<td>M12 x 1.75</td>
<td>84.3</td>
<td>33.7</td>
</tr>
<tr>
<td>M16 x 2</td>
<td>157</td>
<td>62.8</td>
</tr>
<tr>
<td>M20 x 2.5</td>
<td>245</td>
<td>98.0</td>
</tr>
<tr>
<td>M24 x 3</td>
<td>353</td>
<td>141</td>
</tr>
<tr>
<td>M30 x 3.5</td>
<td>561</td>
<td>224</td>
</tr>
<tr>
<td>M36 x 4</td>
<td>817</td>
<td>327</td>
</tr>
</tbody>
</table>

\( ^{\text{A}} \text{Stress area} = 0.7854 \left( D - 0.9382 P \right)^2 \)

where:

- \( D \) = nominal size, mm,
- \( P \) = thread pitch, mm.

### TABLE 6 Values for Length \( x \)

<table>
<thead>
<tr>
<th>Nominal Thread Diameter</th>
<th>( x ), mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1.6</td>
<td>4</td>
</tr>
<tr>
<td>M2</td>
<td>5</td>
</tr>
<tr>
<td>M2.5</td>
<td>6</td>
</tr>
<tr>
<td>M3</td>
<td>8</td>
</tr>
<tr>
<td>M4</td>
<td>10</td>
</tr>
<tr>
<td>M5</td>
<td>12</td>
</tr>
<tr>
<td>M6</td>
<td>14</td>
</tr>
<tr>
<td>M8</td>
<td>20</td>
</tr>
<tr>
<td>M10</td>
<td>25</td>
</tr>
<tr>
<td>M12</td>
<td>30</td>
</tr>
<tr>
<td>M16</td>
<td>40</td>
</tr>
<tr>
<td>M20</td>
<td>45</td>
</tr>
<tr>
<td>M24 and larger</td>
<td>3D</td>
</tr>
</tbody>
</table>

\( ^{\text{A}} x \) equals the minimum length of product subject to tension testing.
10. Test Methods

10.1 Chemical Analysis—The chemical composition shall be determined by any recognized commercial test method. In the event of discrepancy, Test Methods E 353 shall be used for referee purposes.

10.2 Mechanical Tests:

10.2.1 Bolts, screws, and studs are to be tested full size as determined by Table 4 for wedge tensile strength, axial tensile strength, yield strength at 0.2% offset, and hardness in accordance with the methods described in Test Methods F 606M.

10.2.1.1 Test bolts, screws, and studs subject to wedge tension testing using hardened wedges based on the design described in Test Methods F 606M. The wedge shall be 10° when testing hex bolts and screws of nominal thread diameters M20 and smaller and 6° for sizes larger than M20; 6° when testing studs and hex flange screws of nominal thread diameters M20 and smaller and 4° for sizes larger than M20.

10.2.2 Test machined test specimens tested for tensile strength, yield strength, and elongation in accordance with the methods described in Test Methods F 606M.

10.2.3 Extension Test—The extension test is applicable only to full-size products. Measure the overall length of the test specimen \(L_1\). Assemble the specimen into a threaded adapter to a depth of one nominal diameter and then tension-test to failure. Fit the two broken pieces closely together and measure the overall length \(L_2\) again. Compute the total extension by subtracting the original overall length from the length following fracture (Fig. 1). The product is acceptable when the extension equals or exceeds the minimum value for extension specified in Table 2.

10.2.4 Torsional Strength Test:

10.2.4.1 Clamp the sample screw or stud securely by suitable means (Fig. 2) such that the threads in the clamped length are not damaged, and that at least two full threads project above the clamping device, and that a length equal to one nominal diameter, exclusive of point is held within the clamping device. A blind hole may be used in place of a threaded-clamping device, provided the hole depth is such as to ensure that breakage will occur beyond the point. By means of a suitably calibrated torque-measuring device, apply torque to the product until failure occurs. The product is acceptable when the torque required to cause failure equals or exceeds the minimum torsional strength specified in Table 7.

10.2.4.2 The calibrated-torque measuring device shall have a measuring range not exceeding five times and an accuracy of \(\pm 7\%\) of the specified minimum torque value (Table 7) of the product being tested.

10.2.5 For the purposes of determining compliance with the specified limits for properties listed in this specification, an observed value or calculated value shall be rounded in accordance with Practice E 29.

11. Inspection

11.1 If the inspection described in 11.2 is required by the purchaser, it shall be specified in the inquiry, order, or contract.

11.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer’s works that concern
the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection required by the specification that are requested by the purchaser’s representative shall be made prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the work.

12. Rejection and Rehearing

12.1 Unless otherwise specified, any rejection based on tests specified herein and made by the purchaser shall be reported to the manufacturer within 30 working days from the receipt of the product by the purchaser.

13. Certification and Test Reports

13.1 Certificate of Compliance—Unless otherwise specified in the purchase order, the manufacturer shall furnish certifica-

13.2 Test Reports—When specified on the order, the manufacturer shall furnish a test report showing the chemical analysis of the fasteners and the results of the last completed set of mechanical tests for each lot of fasteners in the shipment.

14. Product Marking

14.1 Bolts, Screws, and Studs:

14.1.1 Unless otherwise specified, bolts and screws of nominal thread diameters smaller than M5, and studs M10 and smaller need not be marked. Additionally, slotted and recessed screws of nominal thread diameters M5 and larger need not be marked.

14.1.2 Bolts and screws of nominal thread diameters M5 and larger, and studs larger than M10 shall be marked with a symbol identifying the manufacturer. In addition, they shall be marked with the alloy/mechanical property marking specified in Table 2. The markings shall be raised or depressed at the option of the manufacturer.

14.1.3 When specified on the purchase order, other studs, bolts, and screws shall be marked. Markings shall be in accordance with 14.1.2 or as otherwise ordered by the purchaser.

14.1.4 Markings shall be located on the top of the head and either be raised or depressed at the option of the manufacturer.

15. Packaging and Package Marking

15.1 Packaging:

15.1.1 Unless otherwise specified packaging shall be in accordance with Practice D 3951.

15.1.2 When special packaging requirements are required by the purchaser, they shall be defined at the time of inquiry and order.

15.2 Package Marking—Each shipping unit shall include or be plainly marked with the following:

15.2.1 ASTM specification,

15.2.2 Alloy number,

15.2.3 Alloy/mechanical property marking,

15.2.4 Size,

15.2.5 Name and brand or trademark of the manufacturer,

15.2.6 Number of pieces,

15.2.7 Country of origin,

15.2.8 Purchase order number, and

15.2.9 Lot number, if applicable.

16. Keywords

16.1 bolts; general use; screws; stainless; studs
SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry and order 4.1.6. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Additional Tests
S1.1 When tests for additional mechanical properties, corrosion resistance, etc., are desired by the purchaser, the test(s) shall be made as agreed upon between the manufacturer and the purchaser at the time of the inquiry or order.

S2. Alloy Control
S2.1 When Supplementary Requirement S2 is specified on the inquiry and order, the manufacturer shall supply that alloy specified by the customer on his order with no group substitutions permitted without the written permission of the purchaser.

S3. Permeability
S3.1 When Supplementary Requirement S3 is specified on the inquiry and order, the permeability of bolts, screws, and studs of Grades A1, A2, and A4 in Conditions A or AF shall not exceed 1.5 at 100 oersteds when determined by Test Methods A 342.

S4. Passivation
S4.1 When Supplementary Requirement S4 is specified on the inquiry or order, the finished product shall be passivated in accordance with Practice A 380.

S5. Shipment Lot Testing
S5.1 When Supplementary Requirement S5 is specified on the order, the manufacturer shall make sample tests on the individual lots for shipment to ensure that the product conforms to the specified requirements.

S5.2 The manufacturer shall make an analysis of a randomly selected finished fastener from each lot of product to be shipped. Heat or lot control shall be maintained. The analysis of the starting material from which the fasteners have been manufactured may be reported in place of the product analysis.

S5.3 The manufacturer shall perform mechanical property tests in accordance with this specification and Guide F 1470 on the individual lots for shipment.

S5.4 The manufacturer shall furnish a test report for each lot in the shipment showing the actual results of the chemical analysis and mechanical property tests performed in accordance with Supplementary Requirement S5.

S6. Heat Control
S6.1 When Supplementary Requirement S6 is specified on the inquiry or order, the manufacturer shall control the product by heat analysis and identify the finished product in each shipment by the actual heat number or lot number that is heat lot traceable.

S6.2 When Supplementary Requirement S6 is specified on the inquiry and order, Supplementary Requirements S2 and S5 shall be considered automatically invoked with the addition that the heat analysis shall be reported to the purchaser on the test reports.
Standard Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series

This standard is issued under the fixed designation F 788/F 788M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification establishes allowable limits for the various types of surface discontinuities that may occur during the manufacture and processing of bolts, screws, and studs, including heat-treated machine screws, tapping screws, and sems (the washers of screw-washer assemblies are excluded). This specification covers metric series products with nominal diameters of 4 mm and larger and with specified minimum tensile strengths of 800 MPa and greater; and inch series products with nominal diameters of No. 5 (0.1250 in.) and larger and with specified minimum tensile strengths of 90 000 psi and greater.

1.2 The values stated in either SI (metric) or inch-pound units are to be regarded separately as standard. The values stated in each system are not exact equivalents, therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 When the engineering requirements of the application necessitate control of surface discontinuities on bolts, screws, or studs, the purchaser shall specify conformance to ASTM Specification F 788/F 788M, in the original inquiry and purchase order.

1.3.1 When the engineering requirements of the application necessitate that surface discontinuities on bolts, screws, and studs be controlled within limits closer than those specified in this specification, the purchaser shall specify the applicable limits in the original inquiry and purchase order.

1.4 The allowable limits established in this specification for metric bolts, screws, and studs with nominal diameters from 4 to 24 mm inclusive, are essentially identical with requirements given in ISO 6157/I. There are no ISO standards for surface discontinuities on any inch-series products.

2. Referenced Documents

2.1 ASTM Standards:
E 340 Test Method for Macroetching Metals and Alloys
F 1470 Standard Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
F 1789 Standard Terminology for F16 Mechanical Fasteners
2.2 ISO Standard:
ISO 6157/I Fasteners, Surface Discontinuities on Bolts, Screws and Studs

3. Ordering Information

3.1 Orders for bolts, screws, and studs requiring discontinuity control shall include the following:

3.1.1 ASTM designation and date of issue of this specification.

3.1.2 Special requirements, for example, closer discontinuity limits (1.3.1) and inspection sampling plan (6.2).

4. Types of Surface Discontinuities (see Terminology F 1789 for definitions not provided)

4.1 Crack

4.1.1 Quench Cracks—Typical quench cracks are shown in Fig. 1. Limits are specified in 5.2.

4.1.2 Forging Cracks—Typical forging cracks are shown in Fig. 2. Limits are specified in 5.3.

4.2 Burst—Typical bursts are shown in Fig. 3. Limits are specified in 5.4.

4.2.1 Shear Burst—A shear burst is an open break in the metal located at approximately a 45° angle to the product axis. Shear bursts occur most frequently at the periphery of products having flanged or circular heads. Shear bursts may also occur on the sides of hex-head products. Typical shear bursts are shown in Fig. 3. Limits are specified in 5.4.

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1 This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.93 on Quality Assurance Provisions for Fasteners.


2 Annual Book of ASTM Standards, Vol 03.01.

3 Annual Book of ASTM Standards, Vol 01.08.

4 Available from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

*A Summary of Changes section appears at the end of this standard.

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States.
4.3 Seam—Typical seams are shown in Fig. 4. Limits are specified in 5.5.

4.4 Fold—Typical folds are shown in Fig. 5 a, b, and c. Limits are specified in 5.6.

4.5 Thread Lap—Limits are specified in Supplementary Requirement S.1.1.

4.6 Void—A void is a shallow pocket or hollow on the surface of a bolt or screw due to nonfilling of metal during forging. Voids are produced by marks or impressions of chips (shear burrs) or by rust formation on the raw material. They are not planished during forging. Typical voids are shown in Fig. 6. Limits are specified in 5.7.

4.7 Tool Marks—Tool marks are longitudinal or circumferential grooves of shallow depth produced by the movement of manufacturing tools over the surface of the bolt or screw. Typical tool marks are shown in Fig. 7. Limits are specified in 5.8.

4.8 Gouge—A gouge is an indentation on the surface of a bolt, screw, or stud produced by the forceful abrasion or the impact of a product coming into contact with another product or manufacturing equipment during manufacture, handling, or transport. Limits are specified in 5.9.

5. Allowable Limits

5.1 Letter Definitions—Throughout the following requirements, D designates the nominal size (basic major diameter of thread) of bolts, screws, and studs, except for products with shoulders, in which case D designates the largest shoulder diameter; and Dc designates flange diameter (specified maximum) of circular head products. For metric series products, D and Dc are in millimetres; for inch-series products, D and Dc are in inches.

5.2 Quench Cracks—Quench cracks of any depth, any length, or in any location are not permitted.

5.3 Forging Cracks—Forging cracks on the top of the head of bolts and screws are permitted, provided that (a) no crack shall have a length exceeding 1.0 D, and (b) no crack shall have a width or depth exceeding 0.04 D.

5.4 Bursts and Shear Bursts:

5.4.1 For hex-head bolts and screws, bursts and shear bursts are permitted, provided that (a) no burst or shear burst in the flats extends into the crown (chamfer) circle on the top of the head or into the underhead bearing circle, (b) no burst or shear burst located at the intersection of two wrenching flats reduces the width across corners below its specified minimum, and (c) no burst or shear burst has a width or depth greater than .06 D but not to exceed .062 in. (1.6 mm).

5.4.2 For flange bolts and screws and products with circular heads, bursts and shear bursts at the periphery of the flange or head are permitted, provided that (a) not more than one burst or shear burst has a width greater than 0.04 Dc and (b) the width of the one burst or shear burst that exceeds a width greater than 0.04 Dc does not have a width greater than 0.08 Dc.

5.4.3 For indented head bolts and screws, bursts and shear bursts in the raised periphery of the indented head are permitted, provided that (a) no burst or shear burst has a width greater than 0.06 D and (b) no burst or shear burst has a depth extending below the indented portion.

5.5 Seams:

5.5.1 Seams in the shanks of bolts, screws, and studs are permitted provided that no seam has a depth greater than 0.03 D.

5.5.2 Seams extending into the heads and flanges of bolts and screws are permitted, provided that they do not open beyond the limits specified for bursts and shear bursts in 5.4.

5.6 Folds:

5.6.1 Folds located at interior corners that are at or below the underhead bearing surface, for example, at the junction of head to shank, are not permitted, except for cloverleaf folds.
occurring at the intersection of non-circular shoulders with head bearing face (see Fig. 5a).

5.6.2 Folds located at interior corners that are above the underhead bearing surface, for example, at the junction of the hex head with the top of flange of flange bolts and screws, are permitted (see Fig. 5b).

5.6.3 Folds located at exterior corners are permitted (see Fig. 5c).

5.7 Voids:
5.7.1 Voids on the surfaces of bolts, screws, and studs are permitted, provided that (a) depth of voids does not exceed 0.25 mm or 0.010 in. or 0.02 D, whichever is greater, and (b)
the combined area of all voids on the underhead bearing surface of bolts and screws does not exceed 10% of the specified minimum bearing surface area.

5.7.2 The method for determining the area of voids on the bearing surface shall be as agreed upon between the purchaser and the producer.

5.8 Tool Marks:
5.8.1 Tool marks on the underhead bearing surface are permitted, provided the surface roughness measurement does not exceed 3.2 µm or 125 µin., determined as the arithmetic average deviation from the mean surface.

5.8.2 Tool marks on other surfaces of the product are permitted.

5.9 Nicks and Gouges—Nicks, gouges, dents, and scrapes are permitted, provided that the functionality of the product is not impaired.

6. Inspection and Evaluation

6.1 Bolts, screws, and studs shall be inspected for surface discontinuities in accordance with the procedure in 6.2, 6.3, and 6.4.

6.2 The purchaser shall specify in the original inquiry and purchase order the inspection sampling requirements that the producer must satisfy to demonstrate the acceptability of bolts, screws, and studs with respect to surface discontinuities.

6.3 In the absence of purchaser instructions (6.2), inspection and evaluation shall be in accordance with 6.5.

6.4 For referee purposes, unless other procedures have been specified by the purchaser (6.2), inspection and evaluation shall be in accordance with 6.5.

6.5 Inspection Procedure:
6.5.1 Visual Inspection:
6.5.1.1 A random sample shall be taken from the lot in accordance with F 1470 and examined visually (magnetic particle or fluid penetrant are recommended) for the presence of quench cracks, forging cracks, bursts, shear bursts, seams, folds, voids, tool marks, and nicks and gouges. Visual inspection can include the use of devices that provide up to, and including, 10-power magnification.

6.5.1.2 If, during this inspection, any products are found with quench cracks in any location or with folds at interior corners that are at or below the underhead bearing surface, the lot may be rejected by the purchaser.

6.5.1.3 If, during this inspection, any products are found with any other surface discontinuity, each discontinuity shall be measured, and if any is found that exceeds the allowable dimensional limits for that discontinuity as specified in Section 5, the lot may be rejected by the purchaser.

7. Keywords
7.1 bolts; crack; discontinuities (surface); fold; screw (machine, sems, tapping); seam; studs; thread lap; void

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry and order. Supplementary Requirements shall in no way negate any requirement of the specification itself.

S1. Assemblies Subject to Severe Dynamic Stresses
S1.1 Laps in Screw Threads:
S1.1.1 Laps of any depth and any length which originate below (or originating above and extending below) a point located at a distance equal to or less than 20% of the thread height, measured from the minor diameter, are not permitted. See 4.5 and the Fig. S1.1 and Fig. S1.2.

S1.1.2 Surface discontinuities of threads caused by the thread rolling process, as in Fig. S1.2, shall be excluded from these requirements provided the discontinuities do not exceed the depth of 0.5% × nominal diameter and are essentially parallel to the adjacent thread contour and are not directed toward the screw or bolt axis.

S1.2 Thread Lap Inspection:
S1.2.1 **Visual Inspection**—A random sample shall be selected from the lot in accordance with F 1470. The sample selected shall be surface etched in a 50% solution of HCl and H₂O at approximately 180°F (no more than 5 min of etch time should be employed as excessive etching may remove shallow thread laps). After etch, the samples shall be examined under a 10× magnification for the presence of laps.

S1.2.2 **Microscopic Examination**—If laps are present, one of the samples shall be sectioned longitudinally on the center line of the bolt/screw and on a plane passing through the point at which any lap extends closest to the minor diameter of the thread. The section shall be etched for microscopic examination in accordance with Test Method E 340. Acceptance shall be based on the requirements of S1.1.

**SUMMARY OF CHANGES**

This section identifies the location of selected changes to this specification that have been incorporated since the -97 issue. For the convenience of the user, Committee F16 has highlighted those changes that may impact the use of this specification. This section may also include descriptions of those changes or reasons for the changes, or both.

(1) In 2.1, added Guide F 1470 and Terminology F 1789.
(2) In 4, added reference to Terminology F 1789.
(3) Revised 4.1, 4.1.1, 4.1.2, 4.1.3, 4.2, 4.3, 4.4, 4.5, and 4.8.
(4) In 6.5.1.1, removed reference to Table 1 and added reference to Guide F 1470.
(5) Deleted Table 1.
1. Scope

1.1 This specification establishes allowable limits for the various types of surface discontinuities that may occur during the manufacture and processing of metric-series nuts with nominal diameters 5 mm and larger and inch-series nuts with nominal diameters ¼ in. and larger.

1.2 The values stated in either SI (metric) or inch-pound units are to be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 When the engineering requirements of the application necessitate control of surface discontinuities on nuts, the purchaser shall specify conformance to this ASTM specification in the original inquiry and purchase order.

1.3.1 When the engineering requirements of the application necessitate that surface discontinuities on nuts be controlled within limits closer than those specified in this specification, the purchaser shall specify the applicable limits in the original inquiry and purchase order.

1.4 The allowable limits established in this specification for metric nuts, with nominal diameters 5 to 24 mm inclusive, are essentially identical with requirements given in ISO/DIS 6157/II. There are no ISO standards for surface discontinuities on metric-series nuts with nominal diameters larger than 24 mm or on any inch-series nuts.

1.5 The following precautionary caveat pertains only to the test method portion, Section 7, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

- F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
- F 606M Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets [Metric]
- F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
- F 1789 Terminology for F16 Mechanical Fasteners
- ISO Standard: ISO/DIS 6157/II Fasteners, Surface Discontinuities on Nuts

3. Ordering Information

3.1 Orders for nuts requiring surface discontinuity control shall include:

3.1.1 ASTM designation and date of issue of this specification.

3.1.2 Special requirements, for example, closer discontinuity limits (1.3.1) and inspection sampling plan (6.2).

4. Types of Surface Discontinuities (See Standard F 1789 for definitions not provided)

4.1 Crack:

4.1.1 Quench Cracks—Typical quench cracks are shown in Fig. 1; limits are specified in 5.2.

4.1.2 Forging Cracks—Typical forging cracks are shown in Fig. 2; limits are specified in 5.3.

4.1.3 Inclusion Cracks—Normally caused by nonmetallic inclusions or stringers inherent in the raw material. Typical inclusion cracks are shown in Fig. 2; limits are specified in 5.3.

4.1.4 Locking-Element Cracks—Occur due to application of pressure when forming the locking element of prevailing torque-type nuts. Such cracks are usually located in the vicinity of the locking element and may be either on the internal or external surface. Typical locking element cracks are shown in Fig. 3; limits are specified in 5.4.

4.1.5 Washer-Retainer Cracks—Openings in the lip or hub of metal used to retain a washer on a nut. Washer-retainer...
cracks may occur when pressure is applied to the lip or hub during assembly of the washer. Typical washer-retainer cracks are shown in Fig. 4; limits are specified in 5.5.

4.2 Burst—A typical burst is shown in Fig. 5; limits are specified in 5.6.

4.2.1 Shear Burst—A typical shear burst is shown in Fig. 5; limits are specified in 5.6.

4.3 Seam—Typical seams are shown in Fig. 6; limits are specified in 5.7.

4.4 Fold—Typical folds are shown in Fig. 7; limits are specified in 5.8.

4.5 Void—Voids are produced by marks or impressions of chips (shear burrs) or by rust formation on the raw material. They are not planished during forging. Typical voids are shown in Fig. 8; limits are specified in 5.9.

4.6 Tool Marks—Typical tool marks are shown in Fig. 9; limits are specified in 5.10.

4.7 Nick (Gouge)—Nicks or gouges are produced by the forceful abrasion or the impact of a product coming into contact with another product or manufacturing equipment during manufacture, handling, or transport. Limits are specified in 5.11.

5. Allowable Limits

5.1 Letter Definitions—Throughout the following requirements, D designates the nominal nut size (basic major diameter of thread); Dc designates flange diameter (specified maximum)
on flanged nuts; $S$ designates nominal (specified maximum) width across flats. For metric-series nuts, $D$, $D_c$, and $S$ are in millimetres; for inch series nuts, $D$, $D_c$, and $S$ are in inches.

5.2 Quench Cracks—Quench cracks of any depth, any length, or in any location are not permitted.

5.3 Forging Cracks and Inclusion Cracks—Forging and inclusion cracks located in the top and bottom faces of nuts of all sizes are permitted provided that (a) there are not more than two cracks that extend from the tapped hole across the full width of the face; (b) no crack extends into the tapped hole beyond the first full thread; (c) no crack in the threads exceeds a depth of 0.5 times the thread height; and (d) the width of any crack does not exceed 0.02 $D$ or 0.30 mm or 0.012 in., whichever is greater.

5.3.1 Additionally, hex nuts with nominal diameters 5 to 36 mm inclusive and ¼ to 1½ in. inclusive, showing discontinuity indications, shall meet the requirements of the cone proof load test when sampled in accordance with 6.1, using samples selected in accordance with 6.5.2.

5.4 Locking Element Cracks:

5.4.1 Locking-element cracks (or seams) located on the external surface of the locking element of prevailing torque nuts are permitted provided that the net meets all applicable torque requirements.

5.4.1.1 Additionally, hex nuts with nominal diameters 5 to 36 mm inclusive and ¼ to 1½ in. inclusive, showing discontinuity indications, shall meet the requirements of the cone proof load test when sampled in accordance with 6.1, using samples selected in accordance with 6.5.2.

5.4.2 Locking-element cracks located on the internal surface (threaded or unthreaded) of prevailing torque nuts are permitted provided that (a) no crack exceeds a length of two thread pitches; (b) no crack shall extend into the thread root; and (c) no crack shall have a width exceeding the following:

5.4.2.1 Metric-Series Nuts—0.18 mm for nuts with nominal diameters 5 to 10 mm inclusive, 0.25 mm for nuts with nominal
6. Inspection and Evaluation

6.1 Nuts shall be inspected for surface discontinuities in accordance with the procedures in 6.2, 6.3, and 6.4.

6.2 The purchaser shall specify in the original inquiry and purchase order the inspection sampling requirements which the producer must satisfy to demonstrate the acceptability of nuts with respect to surface discontinuities.

6.3 In the absence of purchaser instructions (6.2), inspection and evaluation shall be in accordance with 6.5.

6.4 For referee purposes, unless other procedures have been specified by the purchaser (6.2), inspection and evaluation shall be in accordance with 6.5.

6.5 Inspection Procedure:

6.5.1 Visual Inspection:

6.5.1.1 A random sample shall be taken from the lot in accordance with Guide F 1470, and examined visually for the presence of quench cracks, forging cracks, inclusion cracks, locking-element cracks, washer retainer cracks, bursts, shear bursts, seams, folds, voids, tool marks, and nicks and gouges.

6.5.1.2 If during this inspection any nuts with quench cracks are found, the lot may be rejected by the purchaser.

6.5.1.3 If during this inspection any nuts found are found with any other surface discontinuity, each discontinuity shall be measured and if any is found that exceeds the allowable dimensional limits for that discontinuity as specified in Section 5, the lot may be rejected by the purchaser.

6.5.1.4 Measurement of Surface Discontinuities in Nuts:

(1) For discontinuities originating from a flat: at the extremity of the discontinuity measure distance D perpendicular to the flat where the discontinuity originated (see Fig. 10).

(2) For discontinuities originating from a corner: at the extremity of the discontinuity measure distance D in a straight line to the corner where the discontinuity originated (see Fig. 10).

6.5.2 Mechanical Testing—During the visual inspection, all hex nuts with nominal diameters 5 to 36 mm inclusive and ¼ to 1½ in. inclusive, that have indications of forging cracks, inclusion cracks, locking-element cracks on external surfaces, or seams, shall be set aside. From this lot, a sample of size in accordance with Guide F 1470, and consisting of those nuts...
indicating the most serious defects, shall be cone proof load tested as specified in 7.1. If any nut fails to meet the requirements of this test, the lot may be rejected by the purchaser.

7. Test Method

7.1 Cone Proof Load Test—If required in 6.5.2, the cone proof load test shall be conducted in accordance with the Cone Proof Load Test Methods F 606 (Inch products), or F 606M (Metric products).

8. Keywords

8.1 Crack; Discontinuities (Surface); Fold; Nut; Seam; Void.
Standard Specification for
Alloy Steel Socket Button and Flat Countersunk Head Cap Screws

This standard is issued under the fixed designation F 835; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This specification covers the requirements for quenched and tempered alloy steel hexagon socket button (SBHCS) 0.060 through 0.625 thread sizes and flat countersunk (SFHCS) 0.060 through 1.5 thread sizes head cap screws having material properties for high-strength requirements.

1.2 Fasteners meeting this specification are intended for shear-type applications and have tensile requirements ranging from 122 to 150 ksi.

1.3 The hazard statement applies only to the test method section, Section 11, of this specification. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
D 3951 Practice for Commercial Packaging
E 3 Practice for Preparation of Metallographic Specimens
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
E 112 Test Methods for Determining Average Grain Size
E 384 Test Method for Microindentation Hardness of Materials
F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

F 788/F 788M Specification for Surface Discontinuities of Bolts, Screws, and Studs. Inch and Metric Series

2.2 ANSI/ASME Standards:

B18.3 Socket Cap, Shoulder and Set Screws—Inch Series
B18.24.1 Part Identifying Number (PIN) Code System

3. Ordering Information

3.1 Orders for material under this specification shall include the following:

3.1.1 Quantity (number of screws).
3.1.2 Dimensions, including nominal thread designation, thread pitch, and nominal screw length (inches). A standard part number may be used for this definition.
3.1.3 Name of the screw: SBHCS or SFHCS.
3.1.4 Coating, if required. If a protective finish other than black oxide is required, it must be specified on the order or product standard.
3.1.5 Lot testing, if required (see 10.3).
3.1.6 Certification, if required (see 14.1).
3.1.7 ASTM designation and year of issue.
3.1.8 Any special requirements.
3.1.9 For establishment of a part identifying system, see ASME B18.24.1.

3.2 Example—1000 pieces 0.250 − 20 0.375 SBHCS lot tensile test. ASTM F 835–XX.

4. Materials and Manufacture

4.1 The screws shall be fabricated from alloy steel made to fine grain practice. In the event of controversy over grain size, referee tests on finished screws conducted in accordance with Test Methods E 112 shall prevail.

4.2 Screws shall be hot or cold upset or extruded, or both.
4.3 Unless otherwise specified, threads shall be rolled for diameters through 0.625 in. and for screw lengths through 4 in. For diameters and lengths other than this, threads may be rolled, cut or ground.

4.4 Screws shall be heat treated by quenching in oil from above the transformation temperature and then tempering by reheating to at least 650°F to be within the hardness range specified in Table 1.

4.4.1 The minimum tempering temperature may be verified by submitting screws to 635°F for 30 min at temperature. The average cross-section hardness of three readings on the screw before and after retempering shall not differ by more than 20 DPH.

4.5 When protective or decorative coatings are applied to the screws, precautions as required by the coatings shall be taken to prevent embrittlement.

5. Chemical Composition

5.1 The chemical composition of the screw material shall conform to the heat analysis specified in Table 2.

5.2 One or more of the following alloying elements, chromium, nickel, molybdenum, or vanadium, shall be present in the steel in sufficient quantity to ensure the specific strength properties are met after oil quenching and tempering. The steel shall meet the AISI definition of alloy steel, that is, maximum and minimum element content requirement or minimum element limits specified.

5.3 Steel to which bismuth, selenium, tellurium, or lead has been added intentionally shall not be permitted.

5.4 Material analysis may be made by the purchaser from finished products and the chemical composition thus determined shall conform to the requirements specified for the product analysis in Table 2.

6. Mechanical Properties

6.1 The finished screws shall conform to the mechanical requirements specified in Table 1.

6.2 Screws having a nominal length equal to or greater than 3 diameters shall be tested full size and shall conform to the full-size tensile requirements specified in Table 3. Tensile failures through the head are acceptable provided the load requirements are satisfied.

6.3 Screws having a nominal thread diameter-length combination as specified in 6.2 and a breaking load exceeding 200 000 lb preferably shall be tested full size and shall meet the full-size tensile properties in Table 3. When equipment of sufficient capacity for such tests is not available or if excessive length of the screws makes full-size testing impractical, standard round machined specimens may be used that shall meet the machined test specimen tensile properties in Table 1. If discrepancy between full-size and machined specimen results, full-size tests shall be used as the referee method to determine acceptance.

6.4 Screws that are too short (lengths less than 3 times nominal size) or that have insufficient threads for tension testing shall not be subject to tension tests but shall conform to the hardness (minimum and maximum) requirements of Table 1.

6.5 All screws, regardless of size, shall conform to the hardness specified in Table 1. Hardness shall be met anywhere on the cross section through the threaded portion one diameter from the screw point.

7. Other Requirements

7.1 Decarburization:
7.1.1 There shall be no evidence of carburization or gross decarburization on the surfaces of the heat-treated screws when measured in accordance with 11.5.

7.1.2 The depth of partial decarburization shall be limited to the values in Table 4 when measured as shown in Fig. 1, and in accordance with 11.5.

7.2 Embrittlement—Coated screws shall withstand the embrittlement test in accordance with 11.4 without showing indications of discontinuities. The loading shall be calculated with minimum screw tensile requirements.

8. Dimensions

8.1 Unless otherwise specified, the dimensions shall conform to the requirements of ANSI/ASME B 18.3.

9. Workmanship, Finish, and Appearance

9.1 Surface Finish—The screws shall have a black (thermal or chemical) oxide finish, unless otherwise specified.

9.2 Surface Discontinuities:

9.2.1 The surface discontinuities for these products shall conform to Specification F 788/F 788M and the additional limitations specified herein.

9.2.2 Forging defects that connect the socket to the periphery of the head are not permissible. Defects originating on the periphery and with a traverse indicating a potential to intersect are not permissible. Other forging defects are permissible, provided those located in the bearing area, fillet and top surfaces shall not have a depth exceeding 0.03\(D\) or 0.005 in., whichever is greater. For peripheral discontinuities, the maximum depth may be 0.06\(D\) not to exceed 0.040 in. (see Fig. 2).

9.2.3 Forging defects located in the socket wall within 0.1 times the actual key engagement, \(T\), from the bottom of the socket are not permissible. Discontinuities located elsewhere in the socket shall not have a length exceeding 0.25\(T\) or a maximum depth of 0.03\(D\) not to exceed 0.005 in. (see Fig. 3).

9.2.4 Seams in the shank shall not exceed a depth of 0.03\(D\) or 0.008 in., whichever is greater.

9.2.5 No transverse discontinuities shall be permitted in the head-to-shank fillet area.

9.2.6 Threads shall have no laps at the root or on the flanks, as shown in Fig. 4. Laps are permitted at the crest (Fig. 4c) that do not exceed 25% of the basic thread depth and on the flanks outside the pitch cylinder. Longitudinal seams rolled beneath the root of the thread and across the crests of cut threads are acceptable within the limits of 9.2.4.

9.2.7 Quench cracks of any depth, any length, or in any location are not permitted.

10. Number of Tests

10.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated. A record of individual heats of steel in each test lot shall be maintained. The container shall be coded to permit identification of the lot.

10.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last complete set of mechanical tests for each stock size in each shipment.

10.3 When additional tests are specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all screws offered for inspection at one time of one diameter and length. From each lot, the number of samples for each requirement shall be as follows:

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and less</td>
<td>1</td>
</tr>
<tr>
<td>Over 800 to 8000, incl</td>
<td>2</td>
</tr>
<tr>
<td>Over 8000 to 22 000, incl</td>
<td>3</td>
</tr>
<tr>
<td>Over 22 000</td>
<td>5</td>
</tr>
</tbody>
</table>

10.4 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be retested for the requirement(s) in which it failed. All of the additional samples shall conform to the specification or the lot shall be rejected.

11. Test Methods

11.1 Chemical analysis shall be conducted in accordance with Test Methods, Practices, and Terminology A 751.

11.2 Tensile properties shall be determined in accordance with Test Methods F 606.

11.3 Hardness shall be determined in accordance with Test Methods E 18.

11.4 Embrittlement tests shall be conducted in accordance with Test Methods F 606. The countersunk washer for the flat countersunk head cap screw shall be placed with the axis of the conical recess at the required wedge angle with the fastener axial load.

11.5 Decarburization and carburization tests shall be conducted as follows:

11.5.1 Section the thread area of the bolt longitudinally through the axis, mount, and polish it in accordance with Guide E 3. Take measurements (1) at the minor diameter in the center of the thread ridge and (2) 0.75\(h\) toward the thread crest on the

### TABLE 4 Decarburization Limits

<table>
<thead>
<tr>
<th>Threads/in.</th>
<th>Thread Height, (h_s)</th>
<th>0.75 (h_s) from Root to Crest, min</th>
<th>0.1 (h_s) at Root, max</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>0.013</td>
<td>0.010</td>
<td>0.001</td>
</tr>
<tr>
<td>44</td>
<td>0.014</td>
<td>0.011</td>
<td>0.001</td>
</tr>
<tr>
<td>40</td>
<td>0.015</td>
<td>0.011</td>
<td>0.002</td>
</tr>
<tr>
<td>36</td>
<td>0.017</td>
<td>0.013</td>
<td>0.002</td>
</tr>
<tr>
<td>32</td>
<td>0.019</td>
<td>0.014</td>
<td>0.002</td>
</tr>
<tr>
<td>28</td>
<td>0.022</td>
<td>0.017</td>
<td>0.002</td>
</tr>
<tr>
<td>24</td>
<td>0.026</td>
<td>0.020</td>
<td>0.003</td>
</tr>
<tr>
<td>20</td>
<td>0.031</td>
<td>0.023</td>
<td>0.003</td>
</tr>
<tr>
<td>18</td>
<td>0.034</td>
<td>0.026</td>
<td>0.003</td>
</tr>
<tr>
<td>16</td>
<td>0.038</td>
<td>0.029</td>
<td>0.004</td>
</tr>
<tr>
<td>14</td>
<td>0.044</td>
<td>0.033</td>
<td>0.004</td>
</tr>
<tr>
<td>13</td>
<td>0.047</td>
<td>0.035</td>
<td>0.005</td>
</tr>
<tr>
<td>12</td>
<td>0.051</td>
<td>0.038</td>
<td>0.005</td>
</tr>
<tr>
<td>11</td>
<td>0.056</td>
<td>0.042</td>
<td>0.006</td>
</tr>
<tr>
<td>10</td>
<td>0.061</td>
<td>0.046</td>
<td>0.006</td>
</tr>
<tr>
<td>9</td>
<td>0.068</td>
<td>0.051</td>
<td>0.007</td>
</tr>
<tr>
<td>8</td>
<td>0.077</td>
<td>0.058</td>
<td>0.008</td>
</tr>
<tr>
<td>7</td>
<td>0.088</td>
<td>0.066</td>
<td>0.009</td>
</tr>
<tr>
<td>6</td>
<td>0.102</td>
<td>0.077</td>
<td>0.010</td>
</tr>
</tbody>
</table>
perpendicular bisector of the thread ridge. Take a measurement (J) on the thread flank approximately at the pitch line at a depth of 0.003 in. Use one of the two methods for carburization/decarburization evaluation either optical or microhardness measurements. The microhardness measurement shall constitute a referee method in case of dispute.

11.5.2 For optical measurement, etch the section in 2 – 4% nital. Examine the surface of the etched samples under a microscope at 100 × using a measuring eyepiece graduated in 0.001-in. increments. The width of any light etching band normally defines the decarburization depth. A dark etching band indicates the possibility of carburization.

11.5.3 Measure microhardness in accordance with Test Method E 384 on unetched specimens using a DPH 136° indenter or a Knoop indenter using the following load application:

<table>
<thead>
<tr>
<th>Number of Threads per Inch</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 40</td>
<td>500 gf</td>
</tr>
<tr>
<td>40, 44, and 48</td>
<td>200 gf</td>
</tr>
<tr>
<td>Over 48</td>
<td>Use optical evaluation in 11.5.2.</td>
</tr>
</tbody>
</table>

11.5.3.1 Take measurements at the minor diameter (Reading Number 1) on the thread crest bisector to determine base metal hardness. Take measurements (Reading Number 2) on the bisector 0.75 h from the minor measurement toward the crest. Also take measurements (Reading Number 3) on the thread flank at the pitch line at a depth within 0.003 from the surface. Reading Number 3 may be taken on the same or an adjacent thread.

11.5.4 Interpret microhardness readings as follows:

11.5.4.1 A decrease of more than 30 hardness points from Reading Number 1 to Reading Number 2 shall be regarded as decarburization and indicates the screw does not conform to specification requirements.

11.5.4.2 An increase of more than 30 hardness points from Reading Number 1 to Reading Number 3 shall be regarded as
carburization and indicates that the screw does not conform to specification requirements.

12. Inspection

12.1 The inspector representing the purchaser, upon reasonable notice, shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser’s representative shall be made before shipment and shall be so conducted as not to interfere unnecessarily with the operation of the works.

13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

14. Certification

14.1 Upon request of the purchaser in the contract or order, a manufacturer’s certification that the material was manufactured and tested in accordance with this specification together with a report of the latest mechanical tests of each stock size in each shipment shall be furnished at the time of shipment.

15. Responsibility

15.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

16. Packaging and Package Marking

16.1 Packaging:

16.1.1 Unless otherwise specified, the packaging shall be in accordance with Practice D 3951.

16.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

16.2 Package Marking:

16.2.1 Each shipping unit shall include or be plainly marked with the following information:

16.2.1.1 ASTM designation,
16.2.1.2 Brand name or trademark of the manufacturer,
16.2.1.3 Number of pieces,
16.2.1.4 Purchase order number, and
16.2.1.5 Country of origin.

17. Keywords

17.1 alloy steel; cap screws; socket button head; socket flat countersunk head; steel
SUMMARY OF CHANGES

This section identifies the location of selected changes to this standard that have been incorporated since the F 835 - 00 issue. For the convenience of the user, Committee F16 has highlighted those changes that impact the use of this standard. This section may also include descriptions of the changes or reasons for the changes, or both.

(1) Deleted the 24 hour test time and deferred to the Test Methods F 606 48 hour test time in 7.2

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

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Standard Specification for
Alloy Steel Socket Button and Flat Countersunk Head Cap Screws [Metric]1

This standard is issued under the fixed designation F 835M; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This specification covers the requirements for quenched and tempered alloy steel hexagon socket button (SBHCS) and
flat countersunk (SFHCS) head cap screws M3 through M20 thread sizes having material properties of ISO 898/1 Property
Class 12.9.

1.2 Fasteners meeting this specification are intended for
shear type applications and have tensile requirements equivalent to ISO 898/1 Property Class 10.9.

1.3 The hazard statement pertains only to the test method
section, Section 11 of this specification. This standard does not
purport to address all of the safety problems, if any, associated
with its use. It is the responsibility of the user of this standard
to establish appropriate safety and health practices and
determine the applicability of regulatory limitations prior to
use.

2. Referenced Documents

2.1 ASTM Standards:
A 751 Test Methods, Practices, and Terminology for
Chemical Analysis of Steel Products2
D 3951 Practice for Commercial Packaging3
E 3 Practice for Preparation of Metallographic Specimens4
E 18 Test Methods for Rockwell Hardness and Rockwell
Superficial Hardness of Metallic Materials4
E 112 Test Methods for Determining Average Grain Size4
E 384 Test Method for Microindentation Hardness of Ma-
terials4
F 606M Test Methods for Determining the Mechanical
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F 788/F 788M Specification for Surface Discontinuities of
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2.2 ANSI/ASME Standards:
B18.3.4M Hexagon Socket Button Head Cap Screws6
B18.3.5M Hexagon Socket Flat Countersunk Head Cap Screws6
B18.24.1 Part Identifying Number (PIN) Code System7
2.3 ISO Standard:
898/1 Mechanical Properties of Fasteners, Bolts, Screws
and Studs6

3. Ordering Information

3.1 Orders for material under this specification shall in-
clude:

3.1.1 Quantity (number of screws).
3.1.2 Dimensions, including nominal thread designation,
thread pitch and nominal screw length (millimetres). A stan-
dard part number may be used for this definition.
3.1.3 Name of the screw: SBHCS or SFHCS.
3.1.4 Coating, if required. If a protective finish other than
black oxide is required, it must be specified on the order or
product standard.
3.1.5 Lot testing, if required (see 10.3).
3.1.6 Certification, if required (see 14.1).
3.1.7 ASTM designation and year of issue, and
3.1.8 Any special requirements.
3.1.9 For establishment of a part identifying system, see
ASME B18.24.1.

3.2 Example—1000 pieces M6 × 1 × 25 SBHCS lot tensile
test, ASTM F 835M – XX.

1 This specification is under the jurisdiction of ASTM Committee F16 on
Fasteners and is the direct responsibility of Subcommittee F 16.02 on Steel Bolts,
Nuts, Rivets, and Washers.


2 Annual Book of ASTM Standards, Vol 01.03.
4 Annual Book of ASTM Standards, Vol 03.01.
5 Available from American National Standards Institute (ANSI), 25 W. 43rd St.,
4th Floor, New York, NY 10036.
6 Available from American Society of Mechanical Engineers (ASME), ASME
International Headquarters, Three Park Ave., New York, NY 10016-5990.

*A Summary of Changes section appears at the end of this standard.
4. Materials and Manufacture

4.1 The screws shall be fabricated from alloy steel made to fine grain practice. In the event of controversy over grain size, referee tests on finished screws conducted in accordance with Test Methods E 112 shall prevail.

4.2 Screws shall be cold upset or extruded, or both.

4.3 Screws shall be roll threaded.

4.4 Screws shall be heat treated by quenching in oil from above the transformation temperature and then tempering by reheating to at least 380°C to be within the hardness range specified in Table 1.

4.4.1 The minimum tempering temperature may be verified by submitting screws to 370°C for 30 min at temperature. The average cross section hardness of three readings on the screw before and after retempering shall not differ by more than 20 DPH.

4.5 When protective or decorative coatings are applied to the screws, precautions as required by the coating, shall be taken to prevent embrittlement.

5. Chemical Composition

5.1 The chemical composition of the screw material shall conform to the heat analysis specified in Table 2.

5.2 One or more of the following alloying elements, chromium, nickel, molybdenum, or vanadium, shall be present in the steel in sufficient quantity to assure the specific strength properties are met after oil quenching and tempering. The steel shall meet the AISI definition of alloy steel, that is, maximum and minimum element content requirement or minimum element limits specified.

5.3 Steel to which bismuth, selenium, tellurium, or lead has been added intentionally shall not be permitted.

5.4 Material analysis may be made by the purchaser from finished products and the chemical composition thus determined shall conform to the requirements specified for the product analysis in Table 2.

6. Mechanical Properties

6.1 The finished screws shall conform to the mechanical requirements specified in Table 1.

6.2 Screws having a nominal thread diameter-length combination equal to or greater than that in Table 1 of Test Methods F 606M shall be tested full size and shall conform to the full size tensile requirements specified in Table 3. Tensile failures through the head are acceptable provided the load requirements are satisfied.

6.3 Screws having a nominal thread diameter-length combination as specified in 6.2 and a breaking load exceeding 535 kN preferably shall be tested full size and shall meet the full-size tensile properties in Table 3. When equipment of sufficient capacity for such tests is not available, or if excessive length of the screws makes full-size testing impractical, standard round machined specimens may be used which shall meet the “machined test specimen tensile properties” in Table 1. If discrepancy between full-size and machined specimen results, full-size tests shall be used as the referee method to determine acceptance.

6.4 Screws that are too short (lengths less than that specified in 6.2 (see also Test Methods F 606M) or that have insufficient threads for tension testing shall not be subject to tension tests but shall conform to the hardness (minimum and maximum) requirements of Table 1.

6.5 All screws, regardless of size, shall conform to the hardness specified in Table 1. Hardness shall be met anywhere on the cross section through the threaded portion one diameter from the screw point.

7. Other Requirements

7.1 Decarburization:

7.1.1 There shall be no evidence of carburization or gross decarburization on the surfaces of the heat-treated screws when measured in accordance with 11.5.

7.1.2 The depth of partial decarburization shall be limited to the values in Table 4 when measured as shown in Fig. 1, and in accordance with 11.5.

7.2 Embrittlement—Coated screws shall withstand the embrittlement test in accordance with 11.4 without showing indications of discontinuities. The loading shall be calculated with minimum screw tensile requirements.

### Table 1: Mechanical Requirements

<table>
<thead>
<tr>
<th>Full-size Screws:</th>
<th>Tensile, min, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machined Test Specimen:</td>
<td>980</td>
</tr>
<tr>
<td>Yield strength at 0.2 % offset, min, MPa</td>
<td>1100</td>
</tr>
<tr>
<td>Tensile strength, min, MPa</td>
<td>1220</td>
</tr>
<tr>
<td>Elongation in 5D, min, %</td>
<td>8</td>
</tr>
<tr>
<td>Reduction of area, min, %</td>
<td>35</td>
</tr>
<tr>
<td>Product Hardness:</td>
<td></td>
</tr>
<tr>
<td>Rockwell</td>
<td>38 to 44 HRC</td>
</tr>
<tr>
<td>Vickers</td>
<td>372 to 434 DPH</td>
</tr>
</tbody>
</table>

### Table 2: Chemical Requirements

<table>
<thead>
<tr>
<th>Element</th>
<th>Composition, %</th>
<th>Heat Analysis</th>
<th>Product Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>0.30 to 0.48</td>
<td>0.28 to 0.50</td>
<td></td>
</tr>
<tr>
<td>Phosphorus, max</td>
<td>0.035</td>
<td>0.040</td>
<td></td>
</tr>
<tr>
<td>Sulfur, max</td>
<td>0.040</td>
<td>0.045</td>
<td></td>
</tr>
</tbody>
</table>

### Table 3: Minimum Ultimate Tensile Loads

<table>
<thead>
<tr>
<th>Thread Size</th>
<th>Stress Area, mm²</th>
<th>Tensile Load, min, kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>M3 × 0.5</td>
<td>5.03</td>
<td>4.93</td>
</tr>
<tr>
<td>M4 × 0.7</td>
<td>8.78</td>
<td>8.60</td>
</tr>
<tr>
<td>M5 × 0.8</td>
<td>14.2</td>
<td>13.9</td>
</tr>
<tr>
<td>M6 × 1</td>
<td>20.1</td>
<td>19.7</td>
</tr>
<tr>
<td>M8 × 1.25</td>
<td>36.6</td>
<td>35.9</td>
</tr>
<tr>
<td>M10 × 1.5</td>
<td>58.0</td>
<td>56.8</td>
</tr>
<tr>
<td>M12 × 1.75</td>
<td>84.3</td>
<td>82.6</td>
</tr>
<tr>
<td>M14 × 2</td>
<td>115</td>
<td>109</td>
</tr>
<tr>
<td>M16 × 2</td>
<td>157</td>
<td>155</td>
</tr>
<tr>
<td>M20 × 2.5</td>
<td>245</td>
<td>240</td>
</tr>
</tbody>
</table>

^ See for alloy requirements.
TABLE 4 Decarburization Limits for Threads

<table>
<thead>
<tr>
<th>Thread-Pitch, P, mm</th>
<th>Basic Thread Height, ( h_s ) = 0.6135P mm</th>
<th>( N = \frac{3}{4}h_s ), mm</th>
<th>( \text{Root } = 0.1h_s ), mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7</td>
<td>0.429</td>
<td>0.322</td>
<td>0.043</td>
</tr>
<tr>
<td>0.8</td>
<td>0.491</td>
<td>0.368</td>
<td>0.049</td>
</tr>
<tr>
<td>1</td>
<td>0.613</td>
<td>0.460</td>
<td>0.061</td>
</tr>
<tr>
<td>1.25</td>
<td>0.767</td>
<td>0.575</td>
<td>0.077</td>
</tr>
<tr>
<td>1.5</td>
<td>0.920</td>
<td>0.690</td>
<td>0.092</td>
</tr>
<tr>
<td>1.75</td>
<td>1.074</td>
<td>0.806</td>
<td>0.107</td>
</tr>
<tr>
<td>2</td>
<td>1.227</td>
<td>0.920</td>
<td>0.123</td>
</tr>
<tr>
<td>2.5</td>
<td>1.534</td>
<td>1.151</td>
<td>0.153</td>
</tr>
</tbody>
</table>

\( ^* \) See Fig. 1.

8. Dimensions

8.1 Unless otherwise specified, the dimensions shall conform to the requirements of ANSI/ASME B18.3.4M or B18.3.5M as specified.

9. Workmanship, Finish and Appearance

9.1 Surface Finish—The screws shall have a black (thermal or chemical) oxide finish, unless otherwise specified.

9.2 Surface Discontinuities:

9.2.1 The surface discontinuities for these products shall conform to Specification F 788/F 788M and the additional limitations specified herein.

9.2.2 Forging defects that connect the socket to the periphery of the head are not permissible. Defects originating on the periphery and with a traverse indicating a potential to intersect are not permissible. Other forging defects are permissible provided those located in the bearing area, fillet, and top surfaces shall not have a depth exceeding 0.03 \( D \) or 0.13 \( m \), whichever is greater. For peripheral discontinuities, the maximum depth may be 0.06 \( D \) not to exceed 1 \( mm \) (see Fig. 2).

9.2.3 Forging defects located in the socket wall within 0.1 times the actual key engagement, \( T \), from the bottom of the socket are not permissible. Discontinuities located elsewhere in the socket shall not have a length exceeding 0.25 \( T \), or a maximum depth of 0.03 \( D \) not to exceed 0.13 \( mm \) (see Fig. 3).

9.2.4 Seams in the shank shall not exceed a depth of 0.03 \( D \) or 0.2 \( mm \), whichever is greater.

9.2.5 No transverse discontinuities shall be permitted in the head-to-shank fillet area.

9.2.6 Threads shall have no laps at the root or on the flanks, as shown in Fig. 4. Laps are permitted at the crest (Fig. 4c) that do not exceed 25 \% of the basic thread depth, and on the flanks outside the pitch cylinder. Longitudinal seams rolled beneath the root of the thread and across the crests of cut threads are acceptable within the limits of 9.2.4.

9.2.7 Quench cracks of any depth, any length, or in any location are not permitted.

10. Number of Tests

10.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated. A record of individual heats of steel in each test lot shall be maintained. The container shall be coded to permit identification of the lot.

10.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last complete set of mechanical tests for each stock size in each shipment.

10.3 When additional tests are specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all screws offered for inspection at one time of one diameter and length. From each lot, the number of samples for each requirement shall be as follows:

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and less</td>
<td>1</td>
</tr>
<tr>
<td>Over 800 to 8000, incl</td>
<td>2</td>
</tr>
<tr>
<td>Over 8000 to 22 000, incl</td>
<td>3</td>
</tr>
<tr>
<td>Over 22 000</td>
<td>5</td>
</tr>
</tbody>
</table>

10.4 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be retested for the requirement(s) in which it failed. All of the additional samples shall conform to the specification or the lot shall be rejected.

11. Test Methods

11.1 Chemical analysis shall be conducted in accordance with Test Methods A 751.

11.2 Tensile properties shall be determined in accordance with Test Methods F 606M.

11.3 Hardness shall be determined in accordance with Test Methods E 18.

11.4 Embrittlement tests shall be conducted in accordance with Test Methods F 606M.

11.5 Decarburization and carburization tests shall be conducted as follows:

11.5.1 Section the thread area of the bolt longitudinally through the axis, mount, and polish it in accordance with Guide E 3. Take measurements (1) at the minor diameter in the center of the thread ridge and (2) 0.75 \( h \) toward the thread crest on the perpendicular bisector of the thread ridge. Take a measurement (3) on the thread flank approximately at the pitch line at a depth of 0.08 \( mm \). Use one of the two methods for carburization/ decarburization evaluation either optical or microhardness measurements. The microhardness measurement shall constitute a referee method in case of dispute.

11.5.2 For optical measurement, etch the section in 2 – 4 \% nital. Examine the surface of the etched samples under a microscope at 100 × using a measuring eyepiece graduated in 0.03-mm increments. The width of any light etching band normally defines the decarburization depth. A dark etching band indicates the possibility of carburization.
11.5.3 Measure microhardness in accordance with Test Method E 384 on unetched specimens using a DPH 136° indenter or a Knoop indenter using the following load application:

<table>
<thead>
<tr>
<th>Thread Pitch, P, min.</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 0.6</td>
<td>500 gf</td>
</tr>
<tr>
<td>0.6</td>
<td>200 gf</td>
</tr>
<tr>
<td>Less than 0.6</td>
<td>Use optical evaluation in 11.5.2</td>
</tr>
</tbody>
</table>

11.5.3.1 Take measurements at minor diameter (Reading Number 1) on the thread crest bisector to determine base metal hardness. Take measurements (Reading Number 2) on the bisector 0.75 \( h \) from the minor measurement toward the crest. Also take measurements (Reading Number 3) on the thread flank at the pitch line at a depth within 0.08 mm from the surface. Reading Number 3 may be taken on the same or an adjacent thread.

11.5.4 Interpret microhardness readings as follows:

11.5.5 A decrease of more than 30 hardness points from Reading Number 1 to Reading Number 2 shall be regarded as decarburization and indicates the screw does not conform to specification requirements.

11.5.6 An increase of more than 30 hardness points from Reading Number 1 to Reading Number 3 shall be regarded as carburization and indicates that the screw does not conform to specification requirements.

12. Inspection

12.1 The inspector representing the purchaser, upon reasonable notice, shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser’s representative shall be made before shipment,
13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

14. Certification

14.1 Upon request of the purchaser in the contract or order, a manufacturer’s certification that the material was manufactured and tested in accordance with this specification, together with a report of the latest mechanical tests of each stock size in each shipment, shall be furnished at the time of shipment.

15. Responsibility

15.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

16. Packaging and Package Marking

16.1 Packaging:
16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.
16.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

16.2 Package Marking:

16.2.1 Each shipping unit shall include or be plainly marked with the following information:
16.2.1.1 ASTM designation,
16.2.1.2 Size,
16.2.1.3 Name and brand or trademark of the manufacturer,
16.2.1.4 Number of pieces,
16.2.1.5 Purchase order number, and
16.2.1.6 Country of origin.

17. Keywords

17.1 alloy steel; cap screws; socket button head; socket flat countersunk head; steel

**SUMMARY OF CHANGES**

This section identifies the location of selected changes to this specification that have been incorporated since the F 835M - 00 issue. For the convenience of the user, Committee F16 has highlighted those changes that may impact the use of this specification. This section may also include descriptions of the changes or reasons for the changes, or both.

(1) Deleted the 24 hour test time and deferred to the Test Methods F 606M 48 hour test time in 7.2.
1. Scope

1.1 This specification covers the chemical and mechanical requirements for stainless steel metric nuts with nominal thread diameters M1.6 through M36 and intended for use in engineering applications requiring general corrosion resistance.

1.2 Eight groups of stainless steel alloys are covered, including three austenitic (Grades A1, A2, and A4), one ferritic (Grade F1), three martensitic (Grades C1, C3, and C4), and one precipitation hardening (Grade P1).

1.3 Seventeen property classes are covered, including nine austenitic, one ferritic, six martensitic, and one precipitation hardening. The property classes with the permissible alloys for each are listed in Table 1.

1.4 This specification is based in concept and content on ISO 3506. The chemical and mechanical requirements specified for all property classes, except as given in 1.4.1, are essentially identical with classes of the same designation in ISO 3506.

1.4.1 This specification includes 13 of the 16 property classes covered in ISO 3506. Additionally, it includes property classes A1-70, A2-70, A4-70, A1-80, A2-80, and A4-80 for products with nominal thread diameters larger than M20; and four non-ISO property classes, C1-110, C4-110, C3-120, and P1-90.

1.5 Supplementary requirements of an optional nature are provided, applicable only when agreed upon between the manufacturer and the purchaser at the time of the inquiry and order.

1.6 Suitable bolts, hex cap screws, and studs for use with nuts included in this specification are covered by Specification F 738M. Unless otherwise specified, all bolts, hex cap screws, and studs used with these nuts shall conform to the requirements of Specification F 738M and shall be of the same alloy group.

2. Referenced Documents

2.1 ASTM Standards:
A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
A 342 Test Methods for Permeability of Feebly Magnetic Materials
A 380 Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
A 493 Specification for Stainless Steel Wire and Wire Rods for Cold Heading and Cold Forging Wire
A 555/A 555M Specification for General Requirements for Stainless Steel Wire and Wire Rods
A 564/A 564M Specification for Hot-Rolled and Cold-Finished Age-Hardenable Stainless Steel Bars and Shapes
A 582 Specification for Free-Machining Stainless Steel Bars
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
D 3951 Practice for Commercial Packaging
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
F 606M Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets [Metric]
F 738M Specification for Stainless Steel Metric Bolts, Screws, and Studs
F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

2.2 ISO Standard:
ISO 3506 Corrosion-Resistant Stainless Steel Fasteners

2.3 ASME Standards:
ASME B1.13M Metric Screw Threads—M Profile
ASME B18.2.4.1M Metric Hex Nuts, Style 1
NOTE 1—The following ASTM standards are noted for information only as suitable sources of material for the manufacture of nuts to this specification: Specifications A 493, A 564, and A 582.

3. Classification

3.1 The designation of each property class is comprised of three parts, a letter followed by a single digit, followed by either two or three digits (see Table 1).

3.1.1 The letter indicates the general composition type of stainless steel:

3.1.1.1 A for austenitic steels,
3.1.1.2 F for ferritic steels,
3.1.1.3 C for martensitic steels, and
3.1.1.4 P for precipitation-hardening steel.

3.1.2 The first digit (1, 2, 3, or 4) indicates the alloy group. The permissible alloys within each group are given in Table 1.

3.1.3 The last two or three digits (50, 70, 110, etc.) indicate 10% of the specified nut proof load stress of the property class.

3.1.4 For example, Class A1-50 is an austenitic steel of any one of six permitted alloys, and the manufactured nut has a proof load stress of 500 MPa.

4. Ordering Information

4.1 Orders for nuts under this specification shall include the following:

4.1.1 Quantity (number of pieces of each item);
4.1.2 Name of item (specific type and style, and references to dimensional standard when appropriate);
4.1.3 Size (nominal diameter, thread pitch);
4.1.4 Property class;
4.1.5 Supplementary requirements, if any (S1 through S3);
4.1.6 Orders for nuts under this specification may include the following optional requirements:

4.1.6.1 Forming (5.1);
4.1.6.2 Alloy condition (5.2);
4.1.6.3 Alloy selection (7.2.1 and S2);
4.1.6.4 Test report (15.2);
4.1.6.5 Additional testing (11.3);
4.1.6.6 Corrosion resistance testing (11.2);
4.1.6.7 Inspection (13.1);
4.1.6.8 Heat number (11.1.1);
4.1.6.9 Certification (15.1);
4.1.6.10 Proof load testing (9.2).

4.1.7 ASTM specification and date of issue. When date of issue is not specified, nuts shall be furnished to the latest issue.

NOTE 2—Example: 10,000 pieces, hex nut, ASME B18.2.4.1M, M6 × 1, Class A2-70, furnish test report, ASTM F 836M – XX.

5. Materials and Manufacture

5.1 Forming—Unless otherwise specified, nuts shall be cold-formed, hot-formed, or machined, at the option of the manufacturer.

5.2 Condition—Nuts shall be furnished in the condition specified for the property class in Table 2. If other conditions are required, the condition and resultant mechanical properties shall be as agreed upon between the manufacturer and the purchaser.

5.3 Surface Finish—Unless otherwise specified, nuts shall be cleaned and descaled in accordance with Practice A 380.

6. Heat Treatment

6.1 Austenitic Alloys, Grades A1, A2, and A4:

6.1.1 When Condition A is specified, the nuts shall be machined from annealed or solution annealed stock, thus retaining the properties of the original material, or hot formed and solution annealed.

6.1.2 When Condition AF is specified, the nuts, following manufacture, shall be annealed by heating to 1040 ± 30°C, at which time the chromium carbide will go into solution. The nuts shall be held for a sufficient time and then cooled at a rate sufficient to prevent precipitation of the carbide and to provide the properties specified in Table 2.

6.1.3 When Condition CW is specified, the austenitic alloy shall be annealed as specified in 6.1.1, and then cold-worked to develop the properties specified in Table 2.

6.1.4 When Condition SH is specified, nuts shall be machined from strain hardened stock.

6.2 Ferritic Alloys, Grade F1:

6.2.1 When Condition A is specified, the ferritic alloy shall be heated to a temperature of 790 ± 30°C, held for an appropriate time, and then air-cooled to provide the properties specified in Table 2.

6.2.2 When Condition AF is specified, nuts shall be treated as specified in 6.1.2.

6.3 Martensitic Alloys, Grades C1, C3, and C4:

6.3.1 When Condition H is specified, the nuts shall be
hardened and tempered by heating to 1010 ± 30°C sufficient for austenitization, holding for at least 1 h and then air-cooling to provide the properties specified in Table 2.

6.3.2 When Condition HT is specified, the nuts shall be hardened and tempered by heating to 1010 ± 30°C sufficient for austenitization, holding for at least 1/2 h, rapid air- or oil-quenching, reheating to 275°C minimum, and holding for at least 1 h and then air-cooling to provide the properties specified in Table 2.

6.4 Precipitation-Hardening Alloy, Grade P1—When Condition AH is specified, the nuts shall be solution-annealed and aged by heating to 1040 ± 15°C, holding for at least 1/2 h, rapid air- or oil-quenching to 27°C maximum, reheating to 620 ± 10°C minimum, holding for 4 h, and then air-cooling to provide the properties specified in Table 2.

7. Chemical Composition

7.1 It is the intent of this specification that nuts shall be ordered by property class.

7.2 Unless otherwise specified in the inquiry and purchase order (see Supplementary Requirement S2), when two or more alloys are permitted for nuts of a specified property class, the choice of alloy to be used shall be that of the fastener manufacturer as determined by his nut fabrication methods and material availability. The specific alloy used by the manufacturer shall be identified clearly on any certification required in the purchase order and shall have a chemical composition conforming to the limits specified in Table 3.

7.2.1 When the purchaser specifies that a specific alloy be used, the alloy shall have a chemical composition conforming to the limits specified in Table 3.

7.3 Product analysis may be made by the purchaser from nuts representing each lot. The chemical composition thus determined shall conform to the limits specified in Table 3 for the specific alloy within the product analysis tolerances specified in Specification A 555.

7.3.1 In the event of discrepancy, a referee analysis of samples for each lot shall be made in accordance with 12.1.

8. Corrosion Resistance

8.1 Carbide Precipitation:

8.1.1 Rod, bar, and wire in the austenitic Alloy Groups A1, A2, and A4, except the free-machining grades, 303 and 303Se, used to make nuts in accordance with this specification, shall be capable of passing the test for susceptibility to intergranular corrosion as specified in Practice E of Practices A 262.

8.1.2 As stated in Practices A 262, samples may be subjected to the faster and more severe screening test in accordance with Practice A. Failing Practice A, specimens may be tested in accordance with Practice E and be considered satisfactory if passing Practice E.

9. Mechanical Properties

9.1 The hardness of nuts of each class shall not exceed the maximum hardness specified for the class in Table 2. This shall

<table>
<thead>
<tr>
<th>Property Class</th>
<th>Conditiona</th>
<th>Alloy/Mechanical Property Marking</th>
<th>Nominal Thread Diameter</th>
<th>Proof Load Stress, MPa</th>
<th>Vickers Hardness min</th>
<th>Vickers Hardness max</th>
<th>Rockwell Hardness min</th>
<th>Rockwell Hardness max</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1-50</td>
<td>A or AF</td>
<td>F836A</td>
<td>M1.6 to M36</td>
<td>500</td>
<td>155</td>
<td>220</td>
<td>B81</td>
<td>B95</td>
</tr>
<tr>
<td>A2-50</td>
<td>A or AF</td>
<td>F836B</td>
<td>M1.6 to M36</td>
<td>700</td>
<td>220</td>
<td>330</td>
<td>B96</td>
<td>C33</td>
</tr>
<tr>
<td>A4-50</td>
<td>A or AF</td>
<td>F836C</td>
<td>M1.6 to M20</td>
<td>800</td>
<td>240</td>
<td>350</td>
<td>C23</td>
<td>C36</td>
</tr>
<tr>
<td>A1-70</td>
<td>CW</td>
<td>F836D</td>
<td>over M20 to M36</td>
<td>1100</td>
<td>350</td>
<td>440</td>
<td>C36</td>
<td>C45</td>
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<tr>
<td>A2-70</td>
<td>SH</td>
<td>F836H</td>
<td>over M20 to M24</td>
<td>800</td>
<td>240</td>
<td>340</td>
<td>C23</td>
<td>C35</td>
</tr>
<tr>
<td>A4-70</td>
<td>SH</td>
<td>F836J</td>
<td>over M24 to M30</td>
<td>1200</td>
<td>380</td>
<td>480</td>
<td>C39</td>
<td>C48</td>
</tr>
<tr>
<td>F1-45</td>
<td>A or AF</td>
<td>F836K</td>
<td>M1.6 to M36</td>
<td>900</td>
<td>285</td>
<td>370</td>
<td>C28</td>
<td>C38</td>
</tr>
<tr>
<td>C1-70</td>
<td>H</td>
<td>F836L</td>
<td>M1.6 to M36</td>
<td>450</td>
<td>135</td>
<td>220</td>
<td>B74</td>
<td>B96</td>
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<tr>
<td>C4-70</td>
<td>H</td>
<td>F836M</td>
<td>M1.6 to M36</td>
<td>700</td>
<td>220</td>
<td>330</td>
<td>B96</td>
<td>C34</td>
</tr>
<tr>
<td>C1-110</td>
<td>HT</td>
<td>F836N</td>
<td>M1.6 to M36</td>
<td>1100</td>
<td>350</td>
<td>440</td>
<td>C36</td>
<td>C45</td>
</tr>
<tr>
<td>C4-110</td>
<td>HT</td>
<td>F836P</td>
<td>M1.6 to M36</td>
<td>800</td>
<td>240</td>
<td>340</td>
<td>C23</td>
<td>C35</td>
</tr>
<tr>
<td>C3-80</td>
<td>HT</td>
<td>F836S</td>
<td>M1.6 to M36</td>
<td>1200</td>
<td>380</td>
<td>480</td>
<td>C39</td>
<td>C48</td>
</tr>
<tr>
<td>C3-120</td>
<td>HT</td>
<td>F836T</td>
<td>M1.6 to M36</td>
<td>900</td>
<td>285</td>
<td>370</td>
<td>C28</td>
<td>C38</td>
</tr>
</tbody>
</table>

a Legend of Conditions:
AF—formed and annealed.
CW—formed from annealed stock, thus acquiring a degree of cold work.
SH—machiined from strain hardened stock.
A—machined from annealed or solution annealed stock, thus retaining the properties of the original material, or not formed and solution annealed.
H—hardened and tempered at 565°C medium.
HT—hardened and tempered at 275°C minimum.
AH—solution annealed and age hardened after forming.

F 836M
be the only hardness requirement for nuts that are proof load tested.

9.2 Unless proof load testing is specified in the inquiry and purchase order, nuts of all classes in nominal thread diameters M4 and smaller, and nuts of all classes with proof loads greater than 530 kN, as specified in Table 4, shall be furnished on the basis of having a hardness not less than the minimum hardness specified in Table 2.

9.3 All classes of nuts, except those covered in 9.2 shall withstand the proof load as specified in Table 4.

10. Dimensions

10.1 Unless otherwise specified, nuts shall conform to dimensions for hex nuts, Style 1, as given in ASME B18.2.4.1M.

10.2 Unless otherwise specified, threads shall be metric coarse threads with class 6H tolerances as specified in ASME B1.13M.

11. Number of Tests and Retests

11.1 The mechanical and chemical composition requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily necessary.

11.1.1 Individual heats of steel are not identified in the finished product. When specified in the purchase order that the heat number shall be identified for the products in an individual shipment, the manufacturer shall control the product by heat analysis and additionally shall conduct the testing program specified in 11.1.

11.2 Unless otherwise specified, tests for corrosion resistance shall be in accordance with the manufacturer’s standard quality control practices. A specific number of tests is not required but the nuts shall be produced by manufacturing practices and subjected to tests and inspection to assure compliance with the specified requirements.

11.2.1 When specified on the purchase order, not less than one corrosion test to determine freedom from precipitated carbides shall be made to represent each lot.

11.3 When the purchaser requires that additional tests be performed by the manufacturer to determine that the properties of nuts in an individual shipment are within specified limits, the purchaser shall specify Supplementary Requirement S1 in the inquiry and purchase order.

11.3.1 When the purchaser does not specify the sampling plan and basis of acceptance the following shall apply:

### TABLE 3 Chemical Requirements

<table>
<thead>
<tr>
<th>Alloy Group</th>
<th>Alloy Designation</th>
<th>Composition, % maximum except as shown</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Car-</td>
</tr>
<tr>
<td>Austenitic Alloys</td>
<td></td>
<td>bon</td>
</tr>
<tr>
<td>A1</td>
<td>303 S30300</td>
<td>0.15</td>
</tr>
<tr>
<td>A1</td>
<td>303Se S30323</td>
<td>0.15</td>
</tr>
<tr>
<td>A1</td>
<td>304 S30400</td>
<td>0.08</td>
</tr>
<tr>
<td>A1</td>
<td>304L S30403</td>
<td>0.03</td>
</tr>
<tr>
<td>A1</td>
<td>305 S30500</td>
<td>0.12</td>
</tr>
<tr>
<td>A1</td>
<td>384 S38400</td>
<td>0.08</td>
</tr>
<tr>
<td>A1</td>
<td>XM1 S20300</td>
<td>0.08</td>
</tr>
<tr>
<td>A1</td>
<td>18–90L S30430</td>
<td>0.10</td>
</tr>
<tr>
<td>A1</td>
<td>302HQ S30433</td>
<td>0.03</td>
</tr>
<tr>
<td>A4</td>
<td>316 S31600</td>
<td>0.08</td>
</tr>
<tr>
<td>A4</td>
<td>316L S31603</td>
<td>0.03</td>
</tr>
<tr>
<td>A4</td>
<td>321 S32100</td>
<td>0.08</td>
</tr>
<tr>
<td>A2</td>
<td>347 S34700</td>
<td>0.08</td>
</tr>
</tbody>
</table>

### Ferritic Alloys

<table>
<thead>
<tr>
<th>Alloy Group</th>
<th>Alloy Designation</th>
<th>Composition, % maximum except as shown</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>430 S43000</td>
<td>0.12</td>
</tr>
<tr>
<td>F1</td>
<td>430F S43020</td>
<td>0.12</td>
</tr>
</tbody>
</table>

### Martensitic Alloys

<table>
<thead>
<tr>
<th>Alloy Group</th>
<th>Alloy Designation</th>
<th>Composition, % maximum except as shown</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>410 S41000</td>
<td>0.15</td>
</tr>
<tr>
<td>C4</td>
<td>416 S41600</td>
<td>0.15</td>
</tr>
<tr>
<td>C4</td>
<td>416Se S41623</td>
<td>0.15</td>
</tr>
<tr>
<td>C5</td>
<td>431 S43100</td>
<td>0.20</td>
</tr>
</tbody>
</table>

### Precipitation Hardening Alloy

<table>
<thead>
<tr>
<th>Alloy Group</th>
<th>Alloy Designation</th>
<th>Composition, % maximum except as shown</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>630 S17400</td>
<td>0.07</td>
</tr>
</tbody>
</table>

⁴ At manufacturer’s option, determined only when intentionally added.
11.3.1.1 The lot, for purposes of selecting samples, shall consist of all nuts offered for inspection and testing, at one time, that are the same type, style, nominal diameter, thread pitch, material (alloy), property class, and surface finish.

11.3.1.2 From each lot, samples shall be selected at random and tested for each requirement in accordance with the following plan:

<table>
<thead>
<tr>
<th>Acceptance Criteria</th>
<th>Number of T ests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Pieces in Lot</td>
<td>Acceptance Number</td>
</tr>
<tr>
<td>800 and less</td>
<td>1</td>
</tr>
<tr>
<td>801 to 8000</td>
<td>2</td>
</tr>
<tr>
<td>8001 to 22 000</td>
<td>3</td>
</tr>
<tr>
<td>Over 22 000</td>
<td>5</td>
</tr>
</tbody>
</table>

11.3.1.3 If the failure of a test specimen is due to improper preparation of the specimen or to incorrect testing technique, the specimen shall be discarded and another test specimen substituted.

12. Test Methods

12.1 Chemical Analysis—Chemical analysis shall be performed in accordance with Test Methods, Practices and Terminology A 751.

12.2 Mechanical Tests:
12.2.1 Hardness and proof load tests of nuts shall be performed in accordance with requirements of Test Methods F 606M.

12.2.2 For nut proof load testing, the speed of testing as determined with a free-running crosshead shall be a maximum of 25 mm/min.

12.3 Corrosion Resistance—Corrosion tests to determine freedom from precipitated carbide shall be performed in accordance with Practice A 262, Practices A or E, as applicable.

12.4 For the purposes of determining compliance with the specified limits for properties listed in this specification, an observed value or calculated value shall be rounded in accordance with Practice E 29.

13. Inspection

13.1 If the inspection described in 13.2 is required by the purchaser, it shall be specified in the inquiry, order, or contract.

13.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection required by the specification that are requested by the purchaser’s representative shall be made prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the work.

14. Rejection and Rehearing

14.1 Unless otherwise specified, any rejection based on tests specified herein and made by the purchaser shall be reported to the manufacturer within 30 working days from the receipt of the product by the purchaser.

15. Certification

15.1 When specified in the purchase order, the manufacturer shall furnish certification that the product was manufactured and tested in accordance with this specification and the purchaser’s order and conforms to all specified requirements.

15.2 When specified in the purchase order, the manufacturer shall furnish a test report certified to be the last complete set of chemical analysis and mechanical tests for each nut size in each shipment.

15.3 All certifications shall indicate the purchase order number.
number and the applicable requirements of Section 4.

16. Product Marking

16.1 Nuts in nominal thread diameters M4 and smaller need not be marked.

16.2 All products with a nominal size of M5 and larger shall be marked with a symbol identifying the manufacturer. In addition, they shall be marked with the alloy/mechanical property marking specified in Table 2. The marking shall be raised or depressed at the option of the manufacturer.

16.3 The manufacturer’s symbol shall be of his design.

16.4 The markings shall be on the top of nut, top of flange, or on one of the wrenching flats.

16.5 Markings located on one of the wrenching flats shall be depressed. Markings on all other locations shall be raised or depressed at the option of the manufacturer.

17. Packaging and Package Marking

17.1 Packaging:

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry and order (4.1.6). Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Additional Tests

S1.1 When tests for additional mechanical properties, corrosion resistance, etc., are desired by the purchaser, the test(s) shall be made as agreed upon between the manufacturer and the purchaser at the time of the inquiry or order.

S2. Alloy Control

S2.1 When Supplementary Requirement S2 is specified on the inquiry and order, the manufacturer shall supply that alloy specified by the customer on his order with no group substitutions permitted without the written permission of the purchaser.

S3. Permeability

S3.1 When Supplementary Requirement S3 is specified on the inquiry and order, the permeability of nuts of Grades A1, A2, and A4 in Conditions A or AF shall not exceed 1.5 at 100 oersteds when determined by Methods A 342.

S4. Shipment Lot Testing

S4.1 When Supplementary Requirement S4 is specified on the order, the manufacturer shall make sample tests on the individual lots for shipment to ensure that the product conforms to the specified requirements.

S4.2 The manufacturer shall make an analysis of a randomly selected finished nut from each lot of product to be shipped. Heat or lot control shall be maintained. The analysis of the starting material from which the nuts have been manufactured may be reported in place of the product analysis.

S4.3 The manufacturer shall perform mechanical property tests in accordance with this specification and Guide F 1470 on the individual lots for shipment.

S4.4 The manufacturer shall furnish a test report for each lot in the shipment showing the actual results of the chemical analysis and mechanical property tests performed in accordance with Supplementary Requirement S4.

S5. Heat Control

S5.1 When Supplementary Requirement S5 is specified on the inquiry or order, the manufacturer shall control the product by heat analysis and identify the finished product in each shipment by the actual heat number or lot number that is heat lot traceable.

S5.2 When Supplementary Requirement S5 is specified on the inquiry or order, Supplementary Requirements S2 and S4 shall be considered automatically invoked with the addition that the heat analysis shall be reported to the purchaser on the test report.
Standard Specification for Stainless Steel Socket Head Cap Screws

1. Scope

1.1 This specification covers the chemical and mechanical requirements for stainless steel inch socket head cap screw (SHCS) with nominal thread 0.060 through 1.500 in. and intended for use in applications requiring general corrosion resistance.

1.2 Two groups of stainless steel alloys are covered, austenitic Group 1 and martensitic Group 5.

1.3 Four property conditions are covered: austenitic Alloy Group 1 in an annealed condition (AF) at 85 ksi maximum, in two cold worked conditions (CW) at 80 ksi minimum, (CW1) at 102 ksi minimum, and martensitic Alloy Group 5 in a heat treated condition (HT) at 160 ksi minimum.

1.4 The following precautionary caveat pertains only to the test method portion, Section 13, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
- A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
- A 342 Test Methods for Permeability of Feebly Magnetic Materials
- A 380 Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
- A 555/A 555M Specification for General Requirements for Stainless Steel Wire and Wire Rods
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- A 967 Specification for Chemical Passivation Treatments for Stainless Steel Parts
- D 3951 Practice for Commercial Packaging
- E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
- E 92 Test Method for Vickers Hardness of Metallic Materials
- E 384 Test Method for Microhardness of Materials
- F 593 Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs
- F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
- F 788/F 788M Specification for Surface Discontinuities on Bolts, Screws, and Studs, Inch and Metric Series
- F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
- ASME Standard:
  ASME B18.3 Socket Cap, Shoulder, and Set Screws—Inch Series

3. Classification

3.1 The designation of the alloy group and condition for the two materials and conditions of this specification shall be consistent with the stainless steel designations in Specification F 593.

3.2 The austenitic stainless steel socket head cap screw shall be designated F 837 Group 1 Condition AF, F 837 Group 1 Condition CW, or F837 Group 1 Condition CW1.

3.3 The martensitic stainless steel socket head cap screw shall be designated F 837 Group 5 Condition HT.

4. Ordering Information

4.1 Orders for socket head cap screws under this specification shall include:

4.1.1 Quantity (number of pieces of each item).
4.1.2 Name of the item (socket head cap screws, SHCS).
4.1.3 Size (nominal diameter, thread pitch, thread class, screw length) or part number.

References:

1 This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.04 on Nonferrous Fasteners.
3 Annual Book of ASTM Standards, Vol 01.03.
5 Annual Book of ASTM Standards, Vol 03.01.
6 Annual Book of ASTM Standards, Vol 01.08.
7 Available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112.
4.1.4 Alloy Group and Condition (Group 1 AF, Group 1 CW, Group 1 CW1, or Group 5 HT).

4.1.5 ASTM specification and year of issue. When year of issue is not specified, fasteners shall be furnished to the latest issue.

4.1.6 Supplementary requirements, if any, (see S1 through S7).

4.1.7 Additional special requirements, if any, to be specified on the purchase order:

4.1.7.1 Forming (see 5.1).

4.1.7.2 Threading (see 5.2).

4.1.7.3 Surface finish (see 11.1).

4.1.7.4 Alloy selection (see 7.2).

4.1.7.5 Test report (see 12.2).

4.1.7.6 Additional testing (see 12.3).

4.1.7.7 Inspection (see 14.1).

4.1.7.8 Rejection (see 15.1).

4.1.7.9 Certification (see 16.1).

4.1.7.10 Special packaging requirements (see 17.2).

4.1.7.11 Supplementary requirements as needed.

5. Materials and Manufacture

5.1 Heads—Unless otherwise specified the head and socket recess of the screw may be hot forged, cold forged, or machined at the option of the manufacturer. Users requiring cold forged heads should specify Supplementary Requirements S1.

5.2 Threads—Unless otherwise specified, screws in sizes up to 1.00 in. inclusive and product lengths up to 6 in. inclusive, shall have threads formed by rolling, except by special agreement with the purchaser. Larger products may be rolled, cut, or ground at the option of the manufacturer.

6. Heat Treatment

6.1 Austenitic alloys Group 1 Condition AF screws, following manufacture, shall be annealed by heating to 1900°F ± 50°F to obtain maximum corrosion resistance and minimum permeability. The screws shall be held for a sufficient time at temperature and then cooled at a rate sufficient to prevent precipitation of the carbide and to provide the properties specified in Table 1.

6.2 When Condition CW or CW1 is specified, the austenitic alloys shall be annealed as specified in 6.1 generally by the raw material manufacturer, then cold worked to develop specific properties.

6.3 Martensitic alloy Group 5 Condition HT screws shall be hardened and tempered by heating to 1800°F ± 50°F sufficient for austenitization, holding for at least 1/2 h, rapid air or oil quenching, reheating to 525°F minimum and holding for at least 1 h and then air cooling to provide the properties specified in Table 1.

7. Chemical Properties

7.1 It is the intent of this specification that screws shall be ordered by alloy group and condition. The chemical composition of the screw material shall conform to the requirements of Table 2.

7.2 Unless otherwise specified in the inquiry and purchase order (see Supplementary Requirements S2) when Alloy Group 1 is specified, the choice of alloy used by the manufacturer shall be clearly identified on all certification required in the purchase order and shall have chemical composition conforming to the limits specified in Table 2.

7.3 When chemical analysis is performed by the purchaser using finished fasteners representing each lot, the chemical contents obtained shall conform to the limits specified in Table 2 for the specific alloy. Chemical contents shall conform to the tolerances specified in Specification A 555/A 555M.

7.3.1 In the event of discrepancy, a referee analysis as specified in 13.1 of samples for each lot shall be made in accordance with 12.3.1.

8. Mechanical Properties

8.1 Screws shall be tested in accordance with the mechanical testing requirements for the alloy group and condition nominal thread diameter, length, and specified minimum tensile strength as specified in Table 3 and shall meet the mechanical requirements specified for that product in Table 1.

8.2 For products on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence over low hardness readings (see Table 4).

9. Corrosion Resistance

9.1 Carbide Precipitation:

9.1.1 Rod, bar, and wire in the austenitic alloy group 1 (not including the free-machining grade 303) used to make fasteners in accordance with this specification shall be capable of passing the test for susceptibility to intergranular corrosion as specified in Practice E of Practice A 262.

### Table 1: Mechanical Property Requirements

<table>
<thead>
<tr>
<th>Alloy Group</th>
<th>Condition</th>
<th>Nominal Thread Diameter</th>
<th>Full-Size Product</th>
<th>Machine Specimen</th>
<th>Core Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tensile Strength, ksi</td>
<td>Minimum Extension</td>
<td>Tensile Strength, ksi</td>
</tr>
<tr>
<td>1</td>
<td>AF</td>
<td>0.060–1.500</td>
<td>85 max</td>
<td>0.6D</td>
<td>85 max</td>
</tr>
<tr>
<td>1</td>
<td>CW</td>
<td>0.060–0.750</td>
<td>80 min</td>
<td>0.4D</td>
<td>80 min</td>
</tr>
<tr>
<td>1</td>
<td>CW1</td>
<td>0.060–0.750</td>
<td>100 min</td>
<td>0.4D</td>
<td>87 min</td>
</tr>
<tr>
<td>5</td>
<td>HT</td>
<td>0.060–0.190</td>
<td>180 min</td>
<td>0.4D</td>
<td>160 min</td>
</tr>
<tr>
<td>5</td>
<td>HT</td>
<td>0.250–1.500</td>
<td>180 min</td>
<td>0.2D</td>
<td>160 min</td>
</tr>
</tbody>
</table>

*For CW and CW1 condition fasteners with normal thread diameter larger than 0.750 in., the mechanical properties shall be agreed upon between the user and manufacturer.

*Core hardness is only required when full-size product tensile testing cannot be accomplished.

*D denotes normal thread size.
9.1.2 As stated in Practices A 262, samples may be subjected to the faster and more severe screening test in accordance with Practice A. Failing Practice A, specimens shall be tested to Practice E and be considered satisfactory if passing Practice E.

10. Dimensions

10.1 Unless otherwise specified, the products shall conform to the requirements of ASME B18.3.

11. Workmanship, Finish, and Appearance

11.1 Surface Treatment—Unless otherwise specified, screws shall be cleaned, descaled and passivated in accordance with Practice A 380 or Specification A 967 at the option of the manufacturer.

11.2 The surface discontinuities for these products shall conform to Specification F 788/F 788M and the additional limitations specified herein.

11.2.1 Forging defects that connect the socket to the periphery of the head are not permissible. Defects originating on the periphery and with a traverse indicating a potential to intersect are not permissible. Other forging defects are permissible provided those located in the bearing area, fillet, and top surfaces shall not have a depth exceeding 0.03 $D$ or 0.005 in, whichever is greater. For peripheral discontinuities, the maximum depth may be 0.06 $D$ (see Fig. 1).

11.2.2 Forging defects located in the socket wall within 0.1 times the actual key engagement, $T$, from the bottom of the socket are not permissible. Discontinuities located elsewhere in the socket shall not have a length exceeding 0.25 $T$, or a maximum depth of 0.03 $D$ not to exceed 0.005 in. (see Fig. 2).

11.2.3 Seams in the shank shall not exceed a depth of 0.03 $D$ or 0.008 in., whichever is greater.

11.2.4 No transverse discontinuities shall be permitted in the head-to-shank fillet area.

11.2.5 Threads shall have no laps at the root or on the flanks located below the pitch line. Laps are permitted at the crests (Fig. 3) that do not exceed 25 % of the basic thread depth, and on the flanks outside the pitch cylinder. Longitudinal seams rolled beneath the root of the thread and across the crests of cut threads are acceptable within the limits of 11.2.3.

12. Number of Tests

12.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of fasteners are not ordinarily necessary. A record of the individual heat of steel in each lot shall be maintained. The containers shall be coded to permit identification of the lot.

12.2 When specified in the purchase order, the manufacturer shall furnish a test report of the last complete set of chemical analysis and mechanical tests for each stock size in each shipment.

12.3 When tests of individual shipments are required, Supplementary Requirement S1 must be specified in the inquiry and order.

### TABLE 2 Chemical Requirements

<table>
<thead>
<tr>
<th>Alloy Group</th>
<th>UNS Designation</th>
<th>Alloy</th>
<th>Composition, % maximum except as shown</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Carbon</td>
</tr>
<tr>
<td>Austenitic Alloys</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>S30300</td>
<td>303A</td>
<td>0.15</td>
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<tr>
<td>1</td>
<td>S30400</td>
<td>304</td>
<td>0.08</td>
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<tr>
<td>1</td>
<td>S30403</td>
<td>304L</td>
<td>0.030</td>
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<tr>
<td>1</td>
<td>S30505</td>
<td>305</td>
<td>0.12</td>
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<tr>
<td>1</td>
<td>S38400</td>
<td>384</td>
<td>0.08</td>
</tr>
<tr>
<td>1</td>
<td>S20300</td>
<td>XM1A</td>
<td>0.08</td>
</tr>
<tr>
<td>1</td>
<td>S30430</td>
<td>18-9LW</td>
<td>0.10</td>
</tr>
<tr>
<td>1</td>
<td>S30433</td>
<td>302HQ</td>
<td>0.03</td>
</tr>
<tr>
<td>1</td>
<td>S31600</td>
<td>316</td>
<td>0.08</td>
</tr>
<tr>
<td>1</td>
<td>S31603</td>
<td>316L</td>
<td>0.03</td>
</tr>
</tbody>
</table>

$^a$ Free machining grades are not recommended for forged product. These grades may be furnished only when approved by the purchaser.

$^b$ At manufacturer’s option, determined only when intentionally added.

### TABLE 3 Mechanical Testing Requirements

<table>
<thead>
<tr>
<th>Item</th>
<th>Product Length</th>
<th>Hardness</th>
<th>Test Conducted Using Full Size Product</th>
<th>Test Conducted Using Machined Test Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>max</td>
<td>min</td>
<td>Extension</td>
</tr>
<tr>
<td>1</td>
<td>$\leq$ 3 $D$</td>
<td>$^a$</td>
<td>$^a$</td>
<td>$^a$</td>
</tr>
<tr>
<td>2</td>
<td>$&gt;$ 3 $D$-12 in.</td>
<td>$^b$</td>
<td>$^b$</td>
<td>$^a$</td>
</tr>
<tr>
<td>3</td>
<td>Over 12 in.</td>
<td>$^b$</td>
<td>$^b$</td>
<td>$^a$</td>
</tr>
</tbody>
</table>

$^a$ $D$ denotes nominal diameter of product.

$^b$ Denotes mandatory test. In addition, either all tests denoted by A or all tests denoted by B shall be performed. In case of arbitration full size tests, denoted A, shall be decisive.
12.3.1 When the purchaser does not specify the sampling plan and basis of acceptance, the following shall apply:

12.3.1.1 The lot, for purposes of selecting samples, shall consist of all products offered for inspection and testing, at one time, that are the same type, style, nominal diameter, thread pitch, nominal length, material (alloy), condition, and surface finish.

12.3.1.2 From each lot, samples shall be selected at random and tested for each requirement in accordance with the following plan:

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and less</td>
<td>1</td>
</tr>
<tr>
<td>Over 800 to 8000, incl.</td>
<td>2</td>
</tr>
<tr>
<td>Over 8000 to 22 000, incl</td>
<td>3</td>
</tr>
<tr>
<td>Over 22 000</td>
<td>5</td>
</tr>
</tbody>
</table>

12.3.1.3 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be retested for the requirement(s) in which it failed.

All of the additional samples shall conform to the specification or the lot shall be rejected.

12.3.1.4 If the failure of a test specimen is due to improper preparation of the specimen or an incorrect testing technique, the specimen shall be discarded and another test specimen submitted.

12.4 Corrosion Resistance Tests:

12.4.1 Unless otherwise specified, inspection for corrosion resistance shall be in accordance with the manufacturer's standard quality control practices. No specific method of inspection is required, but the screws shall be produced from suitable raw material and manufactured by properly controlled practices to maintain resistance to corrosion. When corrosion tests are required, Supplementary Requirement S8 must be specified in the inquiry and order, except as noted in 12.4.2.

12.4.2 Products that have been hot worked shall be solution annealed and tested to determine freedom from precipitated carbides. Not less than one corrosion test shall be made from each lot. Corrosion test shall be performed in accordance with Practice A 262, Practices A or E as applicable.

13. Test Methods

13.1 Chemical Analysis—The chemical composition shall be determined in accordance with Test Method A 751.

13.1.1 The fastener manufacturer may accept the chemical analysis of each heat of raw material purchased and reported on the raw material certification furnished by the raw material producer. The fastener manufacturer is not required to do any further chemical analysis testing, provided that precise heat lot traceability has been maintained throughout the manufacturing process on each lot of fasteners produced and delivered.

13.2 Mechanical Tests:

13.2.1 Screws tested full size for axial strength, screw extension, and hardness shall be tested in accordance with the methods described in Test Methods F 606 and 13.2.3 of this specification. The hardness shall be determined using Test Methods E 18, E 92, or Test Method E 284, as appropriate.

13.2.2 Machined test specimen tests for tensile strength, yield strength at 0.2 % offset, and elongation shall be tested as specified in Test Methods F 606 and 13.2.3 of this specification. The test specimen shall be assembled into a threaded adapter to a depth of one nominal diameter and then axial tensile tested in accordance with 13.2.1 to failure. The two broken pieces shall be fitted closely together and the overall length (L₀) measured. The total extension shall be computed by subtracting the original overall length from the length measurement may be the bottom of the hex socket for the specimen or an incorrect testing technique, when the extension equals or exceeds the minimum value for the specimen shall be discarded and another test specimen submitted.

13.2.3 Extension Test is applicable only to full size products. The overall length of the test specimen (L₀) shall be measured within ±0.005 in. The head and reference surface for length measurement may be the bottom of the hex socket for measuring purposes. The specimen shall be assembled into a threaded adapter to a depth of one nominal diameter and then axial tensile tested in accordance with 13.2.1 to failure. The two broken pieces shall be fitted closely together and the overall length (L₀) measured. The total extension shall be computed by subtracting the original overall length from the length following fracture (Fig. 4). The product is acceptable when the extension equals or exceeds the minimum value for extension specified in Table 1.

13.3 Corrosion Resistance—When specified on the purchase order or inquiry, corrosion tests to determine freedom from precipitated carbides shall be performed in accordance with Practices A 262, Practice A or E as applicable.
14. Inspection

14.1 If the inspection described in 14.1 is required by the purchaser, it shall be specified in the inquiry, order, or contract.

14.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer
shall afford the inspector all reasonable facilities to satisfy that the material is being furnished in accordance with this specification. All tests and inspection required by the specification that are requested by the purchaser’s representative and purchase order shall be made prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the work.

15. Rejection and Rehearing

15.1 Screws that fail to conform to the requirements of this specification may be rejected by the purchaser. Rejection shall be reported to the supplier promptly and in writing. In case of dissatisfaction with the results of tests or inspection authorized by the purchaser, the supplier may claim for a rehearing.

16. Certification

16.1 Test Report—The manufacturer shall maintain on file for a period of 5 years, the original test report, including a copy of the certified chemical analysis of the heat of material used and the results of the required testing for the lot of fasteners.

16.2 Manufacturer’s Certificate of Conformance—The manufacturer shall maintain on file for a period of 5 years, a certificate indicating that the lot of fasteners was manufactured and tested in accordance with this specification and conforms to all specified requirements.

16.3 When requested by the purchaser, submission of copies of the test report, manufacturer’s certificate, or an extension of the 5-year document retention period shall be performed as agreed between the manufacturer and the purchaser at the time of the inquiry or order.

17. Packaging and Package Marking

17. Unless otherwise specified packaging shall be in accordance with Practice D 3951.

17.1 When special packaging requirements are required by the purchaser, they shall be defined at the time of inquiry and order.

17.2 Package Marking—Each shipping unit shall include or be plainly marked with the following:

17.2.1 ASTM specification,
17.2.2 Alloy group and condition,
17.2.3 Alloy number,
17.2.4 Size,
17.2.5 Name and brand or trademark of the manufacturer,
17.2.6 Country of origin,
17.2.7 Number of pieces, and
17.2.8 Purchase order number.

18. Keywords

18.1 corrosion resistant; stainless steel; socket head cap screws
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order. Details of these supplementary requirements shall be agreed upon in writing between the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Shipment Lot Testing

S1.1 When Supplementary Requirement S1 is specified on the order, the manufacturer shall make sample tests on the individual lots for shipment to ensure that the product conforms to the specified requirements.

S1.2 The manufacturer shall make an analysis of a randomly selected finished fastener from each lot of product to be shipped. Heat or lot control shall be maintained. The analysis of the starting material from which fasteners have been manufactured may be reported in place of the product analysis.

S1.3 The manufacturer shall perform mechanical property tests in accordance with this specification and Guide F 1470 on the individual lots for shipment.

S1.4 The manufacturer shall furnish a test report for each lot in the shipment showing the actual results of the chemical analysis and mechanical property tests performed in accordance with Supplementary Requirement S1.

S2. Alloy Control

S2.1 When Supplementary Requirement S2 is specified on the inquiry and order, the manufacturer shall supply that alloy specified by the customer on the order with no group substitutions permitted without the written permission of the purchaser.

S3. Permeability

S3.1 When Supplementary Requirement S3 is specified on the inquiry and order, the permeability of Group 1 condition AF screws shall not exceed 1.05 at 100 oersteds when determined by Test Method A 342. Screws in Group 1 condition CW or CW1 may not be capable of meeting permeability and strength requirements simultaneously. Consultation with the raw material manufacturer should be considered for critical permeability requirements.

S4. Material Identification

S4.1 When Supplementary Requirement S4 is specified on the inquiry and order, the fasteners shall be marked with the specific alloy number to identify the material in accordance with the purchaser’s instructions.

S5. Alloy Condition Identification

S5.1 When Supplementary Requirement S5 is specified on the inquiry and order for nominal sizes ¼ (0.250) in. and larger, the fasteners shall be marked with the alloy condition letters as shown below:

<table>
<thead>
<tr>
<th>Alloy Condition</th>
<th>Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 AF</td>
<td>AF</td>
</tr>
<tr>
<td>Group 1 CW</td>
<td>CW</td>
</tr>
<tr>
<td>Group 1 CW1</td>
<td>CW1</td>
</tr>
<tr>
<td>Group S HT</td>
<td>HT</td>
</tr>
</tbody>
</table>

S6. Manufacturer Identification

S6.1 When Supplementary Requirement S6 is specified on the inquiry and order for nominal sizes ¼ (0.250) in. and larger, the fasteners shall be marked with the manufacturer’s insignia. The manufacturer’s identification insignia shall be of the design, placed on the side or top of the head and recognizable to the purchaser. The insignia shall be readable with no greater than 10× magnification.

S7. Forged Heads

S7.1 When Supplementary Requirement S7 is specified on the inquiry and order, screw heads shall be cold forged by upset, extrusion, or both. The hexagon socket may be forged or machined at the manufacturer’s option. This requirement may be inappropriate for large sizes.

S8. Corrosion Resistance Tests

S8.1 When Supplementary Requirement S8 is specified on the inquiry and order, corrosion test(s) shall be performed as agreed between the manufacturer and the purchaser at the time of the inquiry or order.

S9. Passivation

S9.1 When Supplementary Requirement S9 is specified on the inquiry and order, the finished product shall be passivated in accordance with Specification A 380.
Standard Specification for
Stainless Steel Socket Head Cap Screws [Metric]¹

This standard is issued under the fixed designation F 837M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers the chemical and mechanical requirements for stainless steel metric socket head cap screws (SHCS) with nominal thread M1.6 through M36 and intended for use in applications requiring general corrosion resistance.

1.2 Two groups of stainless steel alloys are covered, austenitic Grade A1 and martensitic Grade C1.

1.3 Four property classes are covered: austenitic A1-50 in an annealed condition at 585 MPa maximum; austenitic A1–55 in a cold worked condition at 550 MPa minimum; austenitic A1-70 in a cold worked condition at 700 MPa minimum, and martensitic C1-110 in a heat treated condition at 1100 MPa minimum.

1.4 This hazard statement pertains only to Section 13, Test Methods: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels²
A 342 Test Methods for Permeability of Feebly Magnetic Materials³
A 380 Practices for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems²
A 555/A555M Specification for General Requirements for Stainless Steel Wire and Wire Rods²
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products²

A 967 Specification for Chemical Passivation Treatments for Stainless Steel Parts²
D 3951 Practice for Commercial Packaging⁴
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials⁵
E 92 Test Method for Vickers Hardness of Metallic Materials⁵
E 384 Test Method for Microhardness of Materials⁵
F 738M Specification for Stainless Steel Metric Bolts, Screws, and Studs⁶
F 788/F788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series⁶
F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection⁶

2.2 ASME Standard:
ASME B 18.3.1M Socket Head Cap Screws (Metric Series)⁷

3. Classification

3.1 The designation of the property class for the two materials and conditions of this specification shall be consistent with the stainless steel designations in Specification F 738M.


3.3 The martensitic stainless steel socket head cap screw shall be designated F837M C1-110.

4. Ordering Information

4.1 Orders for socket head cap screws under this specification shall include:

4.1.1 Quantity (number of pieces of each item),


4.1.3 Metric size (M1.6 through M36).

¹ This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.04 on Nonferrous Fasteners.
³ Annual Book of ASTM Standards, Vol 01.03.
⁴ Annual Book of ASTM Standards, Vol 01.08.
⁵ Annual Book of ASTM Standards, Vol 03.01.
⁶ Annual Book of ASTM Standards, Vol 01.08.
4.1.2 Name of the item (socket head cap screws, SHCS),
4.1.3 Size (nominal diameter, thread pitch, thread class, screw length) or part number,
4.1.4 Property class (A1-50, A1–55, A1-70, or C1-110),
4.1.5 ASTM specification and date of issue. When date of issue is not specified, fasteners shall be furnished to the latest issue,
4.1.6 Supplementary requirements, if any (see S1 through S3),
4.1.7 Additional special requirements, if any, to be specified on the purchase order:
  4.1.7.1 Forming (see 5.1),
  4.1.7.2 Threading (see 5.2),
  4.1.7.3 Surface finish (see 11.1),
  4.1.7.4 Alloy selection (see 7.2),
  4.1.7.5 Test report (see 11.2),
  4.1.7.6 Additional testing (see section 12.3),
  4.1.7.7 Inspection (see 13.1),
  4.1.7.8 Rejection (see 14.1), and
  4.1.7.9 Certification (see 15.1).
4.1.7.10 Special packaging requirements (see section 18.1.2).

5. Material and Manufacture

5.1 Forging—Unless otherwise specified, screws in sizes M3 through M20 with lengths up to 10 times the nominal product diameter or 150 mm, whichever is shorter, shall be cold headed except that they may be hot headed or machined by agreement with the purchaser. Larger sizes and lengths may be cold or hot headed. Screws smaller and larger than the M3 through M36 range may be machined. Sockets may be forged cold or hot headed. Screws smaller and larger than the M3 through M20 with lengths up to 10 times the nominal product diameter or 150 mm, whichever is shorter, shall be cold headed except that they may be hot headed or machined by agreement with the purchaser. Larger sizes and lengths may be cold or hot headed. Screws smaller and larger than the M3 through M36 range may be machined. Sockets may be forged cold or hot headed. Screws smaller and larger than the M3 through M20 with lengths up to 10 times the nominal product diameter or 150 mm, whichever is shorter, shall be cold headed except that they may be hot headed or machined by agreement with the purchaser. Larger sizes and lengths may be cold or hot headed. Screws smaller and larger than the M3 through M36 range may be machined. Sockets may be forged cold or hot headed. Screws smaller and larger than the M3 through M20 with lengths up to 10 times the nominal product diameter or 150 mm, whichever is shorter, shall be cold headed except that they may be hot headed or machined by agreement with the purchaser. Larger sizes and lengths may be cold or hot headed. Screws smaller and larger than the M3 through M36 range may be machined. Sockets may be forged cold or hot headed. Screws smaller and larger than the M3 through M24 inclusive and product lengths up to 150 mm inclusive shall have threads formed by rolling, except by special agreement with the purchaser. Larger products may be rolled, cut, or ground at the option of the manufacturer.

5.2 Threads—Unless otherwise specified, screws in sizes up to M24 inclusive and product lengths up to 150 mm inclusive shall have threads formed by rolling, except by special agreement with the purchaser. Larger products may be rolled, cut, or ground at the option of the manufacturer.

6. Heat Treatment

6.1 Austenitic alloys class A1-50 screws, following manufacture, shall be annealed by heating to 1040 ± 30°C to obtain maximum corrosion resistance and minimum permeability. The screws shall be held for a sufficient time at temperature and then cooled at a rate sufficient to prevent precipitation of the carbide and to provide the properties specified in Table 1.
6.2 When Condition A1-55 or A1-70 is specified, the austenitic alloys shall be annealed as specified in 6.1 generally by the raw material manufacturer, then cold worked to develop specific properties.
6.3 Martensitic alloy Class C1 110 screws shall be hardened and tempered by heating to 1010 ± 30°C sufficient for austenitization, holding for at least ½ h, rapid air or oil quenching, reheating to 275°C minimum and holding for at least 1 h and then air cooling to provide the properties specified in Table 1.

7. Chemical Composition

7.1 It is the intent of this specification that screws shall be ordered by property class. The chemical composition of the screw material shall conform to the requirements of Table 2.
7.2 Unless otherwise specified in the inquiry and purchase order (see Supplementary Requirement S2) when A1-50, A1-55, or A1-70 property class is specified, the choice of alloy used by the manufacturer shall be clearly identified on all certification required in the purchase order. The chemical composition shall conform to the limits specified in Table 2.
7.3 When chemical analysis is performed by the purchaser using finished fasteners representing each lot, the chemical contents obtained shall conform to the limits specified in Table 2 for the specific alloy. Chemical contents shall conform to the tolerances specified in Specification A 555/A 555M.
7.3.1 In the event of discrepancy, a referee analysis as specified in 13.1 of samples for each lot shall be made in accordance with 12.3.1.1.

8. Mechanical Properties

8.1 Screws shall be tested in accordance with the mechanical testing requirements for the property class, nominal thread diameter, length, and specified minimum tensile strength as specified in Table 3 and shall meet the mechanical requirements specified for that product in Table 1.
8.2 For products on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence over low hardness readings (see Table 4).

9. Corrosion Resistance

9.1 Carbide Precipitation:

---

**TABLE 1 Mechanical Property Requirements**

<table>
<thead>
<tr>
<th>Property Class</th>
<th>Nominal Thread Diameter</th>
<th>Full Size Product Tests</th>
<th>Machined Specimen Tests</th>
<th>Core Hardness&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tensile Strength, MPa</td>
<td>Tensile Strength, MPa</td>
<td>Elongation, %</td>
</tr>
<tr>
<td>A1–50</td>
<td>M1.6 to M36</td>
<td>585 max</td>
<td>585 max</td>
<td>380 max</td>
</tr>
<tr>
<td>A1–55</td>
<td>M1.6 to M20</td>
<td>550 min</td>
<td>550 min</td>
<td>270 min</td>
</tr>
<tr>
<td>A1–70</td>
<td>M1.6 to M20</td>
<td>700 min</td>
<td>600 min</td>
<td>450 min</td>
</tr>
<tr>
<td>C1–110</td>
<td>M1.6 to M5</td>
<td>1100</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M6 to M36</td>
<td>1100</td>
<td>1100</td>
<td>820</td>
</tr>
</tbody>
</table>

<sup>a</sup> For A1–55 and A1–70 property class fasteners with nominal thread diameter larger than M20, the mechanical properties shall be agreed upon between the user and manufacturer.
<sup>b</sup> Core hardness is only required when full-size product tensile testing cannot be accomplished.
<sup>c</sup> D denotes nominal thread size.
9.1.1 Rod, bar, and wire in the austenitic alloy group A1 (not including the free-machining grade 303) used to make fasteners in accordance with this specification shall be capable of passing the test for susceptibility to intergranular corrosion as specified in Practice E of Practices A 262.

9.1.2 As stated in Practices A 262, samples may be subjected to the faster and more severe screening test in accordance with Practice A. Failing Practice A, specimens shall be tested to Practice E and be considered satisfactory if passing Practice E.

10. Dimensions

10.1 Unless otherwise specified, the products shall conform to the requirements of ASME B18.3.1M Hexagon Socket Head Cap Screws (Metric Series).

11. Workmanship, Finish, and Appearance

11.1 Surface Treatment—Unless otherwise specified, screws shall be cleaned, descaled and passivated in accordance with Practice A 380 or Specification A 967 at the option of the manufacturer.

11.2 The surface discontinuities for these products shall conform to Specification F 788/F 788M and the additional limitations specified herein.

11.2.1 Forging defects that connect the socket to the periphery of the head are not permissible. Defects originating on the periphery and with a traverse indicating a potential to intersect are not permissible. Other forging defects are permissible provided those located in the bearing area, fillet, and top areas are passed in accordance with Practice E.

### TABLE 2 Chemical Requirements

<table>
<thead>
<tr>
<th>Property Class</th>
<th>UNS Designation</th>
<th>Alloy</th>
<th>Composition, % maximum except as shown</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Carbon</td>
</tr>
<tr>
<td>Austenitic Alloys</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>S30300</td>
<td>303</td>
<td>0.15</td>
</tr>
<tr>
<td>A1</td>
<td>S30400</td>
<td>304</td>
<td>0.08</td>
</tr>
<tr>
<td>A1</td>
<td>S30403</td>
<td>304L</td>
<td>0.030</td>
</tr>
<tr>
<td>A1</td>
<td>S30500</td>
<td>305</td>
<td>0.12</td>
</tr>
<tr>
<td>A1</td>
<td>S38400</td>
<td>384</td>
<td>0.08</td>
</tr>
<tr>
<td>A1</td>
<td>S20300</td>
<td>XM1A</td>
<td>0.08</td>
</tr>
<tr>
<td>A1</td>
<td>S30430</td>
<td>18–9LW</td>
<td>0.10</td>
</tr>
<tr>
<td>A1</td>
<td>S30433</td>
<td>302HQ</td>
<td>0.03</td>
</tr>
<tr>
<td>A1</td>
<td>S31600</td>
<td>316</td>
<td>0.08</td>
</tr>
<tr>
<td>A1</td>
<td>S31603</td>
<td>316L</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Martensitic Alloys

<table>
<thead>
<tr>
<th>Property Class</th>
<th>UNS Designation</th>
<th>Alloy</th>
<th>Composition, % maximum except as shown</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Carbon</td>
</tr>
<tr>
<td>C1</td>
<td>S4100</td>
<td>410</td>
<td>0.15</td>
</tr>
</tbody>
</table>

9.1.2 Free machining grades are not recommended for forged product. These grades may be furnished only when approved by the purchaser.

9.1.3 At manufacturer’s option, determined only when intentionally added.

### TABLE 3 Mechanical Testing Requirements

<table>
<thead>
<tr>
<th>Item</th>
<th>Product Length</th>
<th>Hardness</th>
<th>Test conducted Using Full Size Product</th>
<th>Test Conducted Using Machined Test Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Extension</td>
<td>Axial Tensile Strength</td>
</tr>
<tr>
<td>1</td>
<td>&lt;=3 D  ^a</td>
<td>a</td>
<td>a</td>
<td>. . .</td>
</tr>
<tr>
<td>2</td>
<td>3 D to 300 mm</td>
<td>a</td>
<td>. . .</td>
<td>. . .</td>
</tr>
<tr>
<td>3</td>
<td>Over 300 mm</td>
<td>a</td>
<td>. . .</td>
<td>. . .</td>
</tr>
</tbody>
</table>

^a D denotes nominal diameter of product.

^b Denotes mandatory test. In addition, either all tests denoted by A or all tests denoted by B shall be performed. In case of arbitration, full-size tests, denoted A, shall be decisive.

### TABLE 4 Tensile Strength Values for Full Size Fasteners, kN

<table>
<thead>
<tr>
<th>Nominal Size and Thread Pitch</th>
<th>Stress Area, mm  ^2</th>
<th>Property Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1.6 x 0.35</td>
<td>1.27</td>
<td>0.74</td>
</tr>
<tr>
<td>M2 x 0.4</td>
<td>2.07</td>
<td>1.21</td>
</tr>
<tr>
<td>M2.5 x 0.45</td>
<td>3.39</td>
<td>1.98</td>
</tr>
<tr>
<td>M3 x 0.5</td>
<td>5.03</td>
<td>2.94</td>
</tr>
<tr>
<td>M3.5 x 0.6</td>
<td>6.78</td>
<td>3.97</td>
</tr>
<tr>
<td>M4 x 0.7</td>
<td>8.78</td>
<td>5.14</td>
</tr>
<tr>
<td>M5 x 0.8</td>
<td>14.2</td>
<td>8.30</td>
</tr>
<tr>
<td>M6 x 1</td>
<td>20.1</td>
<td>11.8</td>
</tr>
<tr>
<td>M8 x 1.25</td>
<td>36.6</td>
<td>21.4</td>
</tr>
<tr>
<td>M10 x 1.5</td>
<td>58.0</td>
<td>33.9</td>
</tr>
<tr>
<td>M12 x 1.75</td>
<td>84.3</td>
<td>49.3</td>
</tr>
<tr>
<td>M14 x 2</td>
<td>115</td>
<td>67.5</td>
</tr>
<tr>
<td>M16 x 2</td>
<td>157</td>
<td>91.7</td>
</tr>
<tr>
<td>M20 x 2.5</td>
<td>245</td>
<td>143</td>
</tr>
<tr>
<td>M24 x 3</td>
<td>353</td>
<td>206</td>
</tr>
<tr>
<td>M30 x 3.5</td>
<td>561</td>
<td>328</td>
</tr>
<tr>
<td>M36 x 4</td>
<td>817</td>
<td>478</td>
</tr>
</tbody>
</table>

^A Stress Area = 0.7854 ( D - 0.9382 P )

where:

D = nominal thread diameter, mm, and
P = thread pitch, mm.

^a Tensile based on stress area and 585 MPa maximum.

^b Tensile based on stress area and 550 MPa minimum through M20.

^c Tensile based on stress area and 700 MPa minimum through M20.

^d Tensile based on stress area and 1100 MPa minimum.
surfaces shall not have a depth exceeding 0.03 \( D \) or 0.13 m, whichever is greater. For peripheral discontinuities, the maximum depth may be 0.06 \( D \) (see Fig. 1).

11.2.2 Forging defects located in the socket wall within 0.1 times the actual key engagement, \( T \), from the bottom of the socket are not permissible. Discontinuities located elsewhere in the socket shall not have a length exceeding 0.25 \( T \), or a maximum depth of 0.03 \( D \) not to exceed 0.13 mm (see Fig. 2).

11.2.3 Seams in the shank shall not exceed a depth of 0.03 \( D \) or 0.2 mm, whichever is greater.

11.2.4 No transverse discontinuities shall be permitted in the head-to-shank fillet area.

11.2.5 Threads shall have no laps at the root or on the flanks, as shown in Fig. 3. Laps are permitted at the crests (Fig. 3c) that do not exceed 25 % of the basic thread depth, and on the flanks outside the pitch cylinder. Longitudinal seams rolled beneath the root of the thread and across the crests of cut threads are acceptable within the limits of 11.2.3.

12. Number of Tests

12.1 The requirements of this specification shall be met in continuous mass production for stock and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of fasteners are not ordinarily necessary.

A record of the individual heat of steel in each lot shall be maintained. The containers shall be coded to permit identification of the lot.

12.2 When specified in the purchase order, the manufacturer shall furnish a test report of the last complete set of chemical analysis and mechanical tests for each stock size in each shipment.

12.3 When tests of individual shipments are required, Supplementary Requirement S1 must be specified in the inquiry and order.

12.3.1 When the purchaser does not specify the sampling plan and basis of acceptance, the following shall apply:

12.3.1.1 The lot, for purposes of selecting samples, shall consist of all products offered for inspection and testing, at one time, that are the same type, style, nominal diameter, thread pitch, nominal length, material (alloy), property class, and surface finish.

12.3.1.2 From each lot, samples shall be selected at random and tested for each requirement in accordance with the following plan:

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and less</td>
<td>1</td>
</tr>
<tr>
<td>Over 800 to 8000, incl</td>
<td>2</td>
</tr>
<tr>
<td>Over 8000 to 22 000, incl</td>
<td>3</td>
</tr>
<tr>
<td>Over 22 000</td>
<td>5</td>
</tr>
</tbody>
</table>

A record of the individual heat of steel in each lot shall be maintained. The containers shall be coded to permit identification of the lot.
12.3.1.3 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be retested for the requirement(s) in which it failed. All of the additional samples shall conform to the specification or the lot shall be rejected.

12.3.1.4 If the failure of a test specimen is due to improper preparation of the specimen or an incorrect testing technique, the specimen shall be discarded and another test specimen submitted.

12.4 Corrosion Resistance Tests:

12.4.1 Unless otherwise specified, inspection for corrosion resistance shall be in accordance with the manufacturer’s standard quality control practices. No specific method of inspection is required but the screws shall be produced from suitable raw material and manufactured by properly controlled practices to maintain resistance to corrosion. When corrosion tests are required, Supplementary Requirement S5 must be specified in the inquiry and order, except as noted in 12.4.2.

12.4.2 Products that have been hot worked shall be solution annealed and tested to determine freedom from precipitated
carbides. Not less than one corrosion test shall be made from each lot. Corrosion tests shall be performed in accordance with Practices A 262, Practices A or E as applicable.

13. Test Methods

13.1 Chemical Analysis—The chemical composition shall be determined in accordance with Test Method A 751.

13.1.1 The fastener manufacturer may accept the chemical analysis of each heat of raw material purchased and reported on the raw material certification furnished by the raw material producer. The fastener manufacturer is not required to do any further chemical analysis testing provided that precise heat lot traceability has been maintained throughout the manufacturing process on each lot of fasteners produced and delivered.

13.2 Mechanical Tests:

13.2.1 Screws tested full size for axial strength, screw extension, and hardness shall be tested in accordance with the methods described in Test Methods F 606M and 13.2.3 of this specification. The hardness shall be determined using Test Methods E 18, E 92, or E 384, as appropriate.

13.2.2 Machined test specimens tested for tensile strength, yield strength at 0.2 % offset, and elongation shall be tested in accordance with the methods described in Test Methods F 606M.

13.2.3 Extension Test is applicable only to full size products. The overall length of the test specimen \( L_1 \) shall be measured within ±0.12 mm. The head end reference surface for length measurement may be the bottom of the hex socket for measuring purposes. The specimen shall be assembled into a threaded adapter to a depth of one nominal diameter and then axial tensile tested in accordance with 13.2.1 to failure. The two broken pieces shall be fitted closely together and the overall length \( L_2 \) measured again. The total extension shall be computed by subtracting the original overall length from the length following fracture (Fig. 4). The product is acceptable when the extension equals or exceeds the minimum value for extension specified in Table 1.

13.3 Corrosion Resistance—When specified on the purchase order or inquiry, corrosion tests to determine freedom from precipitated carbides shall be performed in accordance with Practices A 262, Practice A or E as applicable.

14. Inspection

14.1 If the inspection described in 14.2 is required by the purchaser, it shall be specified in the inquiry, order, or contract.

14.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy that the material is being furnished in accordance with this specification. All tests and inspection required by the specification that are requested by the purchaser’s representative and purchase order shall be made prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the work.

15. Rejection and Rehearing

15.1 Screws that fail to conform to the requirements of this specification may be rejected by the purchaser. Rejection shall be reported to the supplier promptly and in writing. In case of dissatisfaction with the results of tests or inspection authorized by the purchaser, the supplier may claim for a rehearing.

16. Certification

16.1 Test Report—The manufacturer shall maintain on file for a period of 5 years the original test report, including a copy of the certified chemical analysis of the heat of material used and the results of the required testing for the lot of fasteners.

16.2 Manufacturer’s Certificate of Conformance—The manufacturer shall maintain on file for a period of 5 years, a certificate indicating that the lot of fasteners was manufactured and tested in accordance with this specification and conforms to all specified requirements.

16.3 When requested by the purchaser, submission of copies of the test report, manufacturer’s certificate or an extension of the 5-year document retention period shall be performed as agreed between the manufacturer and the purchaser at the time of the inquiry or order.

17. Product Marking

17.1 Screws, of nominal thread diameters M5 and larger, shall be marked to identify the property class and the manufacturer. The property class symbol shall be as given below. The manufacturer’s insignia shall be of his design. Markings may be on the side or top of the head and shall be readable with no greater than 10× magnification.

<table>
<thead>
<tr>
<th>Product Identification</th>
<th>Property Class Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alloy Grade</td>
<td>Property Class Symbol</td>
</tr>
<tr>
<td>A1</td>
<td>A1-50</td>
</tr>
<tr>
<td>A1</td>
<td>A1-55</td>
</tr>
<tr>
<td>A1</td>
<td>A1-70</td>
</tr>
<tr>
<td>C1</td>
<td>C1-110</td>
</tr>
</tbody>
</table>

18. Packaging and Package Marking

18.1 Packaging:

18.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.
18.1.2 When special packaging requirements are required by the purchaser, they shall be defined at the time of inquiry and order.

18.2 Package Marking—Each shipping unit shall include or be plainly marked with the following:

18.2.1 ASTM specification,
18.2.2 Property class symbol,
18.2.3 Alloy number,
18.2.4 Size,
18.2.5 Name and brand or trademark of the manufacturer,
18.2.6 Country of origin,
18.2.7 Number of pieces, and
18.2.8 Purchase order number.

19. Keywords

19.1 corrosion resistance; stainless steel; socket head cap screws

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry and order (see 4.1.6). Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Shipment Lot Testing

S1.1 When Supplementary Requirement S1 is specified on the order, the manufacturer shall make sample tests on the individual lots for shipment to ensure that the product conforms to the specified requirements.

S1.2 The manufacturer shall make an analysis of a randomly selected finished fastener from each lot of product to be shipped. Heat or lot control shall be maintained. The analysis of the starting material from which the fasteners have been manufactured may be reported in place of the product analysis.

S1.3 The manufacturer shall perform mechanical property tests in accordance with this specification and Guide F 1470 on the individual lots for shipment.

S1.4 The manufacturer shall furnish a test report for each lot in the shipment showing the actual results of the chemical analysis and mechanical property tests performed in accordance with Supplementary Requirement S1.

S2. Alloy Control

S2.1 When Supplementary Requirement S2 is specified on the inquiry and order, the manufacturer shall supply that alloy specified by the customer on his order with no group substitutions permitted without the written permission of the purchaser.

S3. Permeability

S3.1 When Supplementary Requirement S3 is specified on the inquiry and order, the permeability of Property Class A1-50 screws shall not exceed 1.05 at 100 oersteds when determined by Test Method A 342. Screws in Property Class A1-55 or A1-70 may not be capable of meeting permeability and strength requirements simultaneously. Consultation with the raw material manufacturer should be considered for critical permeability requirements.

S4. Material Identification

S4.1 When Supplementary Requirement S4 is specified on the inquiry and order for nominal sizes M5 (5 mm) and larger, the fasteners shall be marked with the specific alloy number to identify the material in accordance with the purchaser’s instructions, and with the manufacturer’s insignia. The manufacturer’s identification insignia shall be of the design, placed on the side or top of the head and known and recognizable to the purchaser. The insignia shall be readable with no greater than 10\\(^3\) magnification.

S5. Corrosion Resistance Tests

S5.1 When Supplementary Requirement S5 is specified on the inquiry and order, corrosion test(s) shall be performed as agreed between the manufacturer and the purchaser at the time of the inquiry or order.

S6. Passivation

S6.1 When Supplementary Requirement S6 is specified on the inquiry and order, the finished product shall be passivated in accordance with Specification A 380.
Standard Specification for Washers, Steel, Plain (Flat), Unhardened for General Use

This standard is issued under the fixed designation F 844; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope *

1.1 This specification covers round and miscellaneous shape steel plain (flat) washers furnished in an unhardened condition.

1.2 The washers are intended for general use bolt, nut, and stud applications to provide increased bearing surface, spacing, and to prevent galling.

1.3 Unless otherwise specified, the washers are furnished with dimensions conforming to American National Standard B18.22.1 , Type A, Tables 1A and Tables 1B.

1.4 Hardened washers for use with heat-treated structural bolts are covered by Specifications F 436 and F 436M.

2. Referenced Documents

2.1 ASTM Standards:
   A 29/A29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for
   A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
   A 568/A568M Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for
   A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
   B 633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel
   B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
   D 3951 Practice for Commercial Packaging
   F 436 Specification for Hardened Steel Washers
   F 436M Specification for Hardened Steel Washers [Metric]
   F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
   F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

2.2 ANSI/ASME Standards:
   B18.22.1 Plain Washers
   B18.24.1 Part Identifying Number (PIN) Code System
   Military Specification:
   DOD-P-16232 Phosphate Coating for Ferrous Metals
   Federal Specification:
   QQ-P-416 Plating, Cadmium (Electrodeposited)

3. Ordering Information

3.1 Orders for washers under this specification shall include:
   3.1.1 Quantity (number of pieces of same item and size).
   3.1.2 Name of item (steel plain washers).
   3.1.3 Size (Nominal inside diameter and thickness. Include outside diameter, when required).
   3.2 The following requirements are optional and may be specified when required:
   3.2.1 Dimensions if other than ANSI B18.22.1, Type A.
   3.2.2 Finish if other than oiled (see 4.3 through 4.3.6).
   3.2.3 Chemical composition, if required (see 5.1.2).
   3.2.4 Hardness, if required (see 6.2).
   3.2.5 Shipment lot Testing, if required (see 9.2).
   3.2.6 Test Reports, if required (see Section 12).
   3.2.7 Marking, if required (see 14.1).
   3.2.8 For establishment of a part identifying system, see ASME B18.24.1.

4. Materials and Manufacture

4.1 Material—The washers shall be punched from hot-rolled, hot-rolled and pickled, or cold-rolled steel; or shall be machined from bar stock or tubing; or shall be forged at the manufacturer’s option.

4.2 Burr Removal—The washers shall be tumbled, vibrated, or otherwise processed to minimize burrs.

4.3 Protective Finishes:
   4.3.1 Unprotected Washers—Unless otherwise specified, the washer shall be furnished plain, with no protective finish other than oil to minimize rusting.
4.3.2 Zinc Coatings, Hot-Dip and Mechanically Deposited:
4.3.2.1 When zinc-coated washers are required, the purchaser shall specify the zinc-coating process, such as “hot dip,” “mechanically deposited,” or “no preference.”
4.3.2.2 When “hot-dip” is specified, the washers shall be zinc-coated by hot dipping in accordance with the requirements of Class C of Specification A 153.
4.3.2.3 When “mechanically deposited” is specified, the washers shall be zinc-coated by mechanical deposition in accordance with the requirements of Class 50 of Specification B 695.
4.3.2.4 When “no preference” is specified, the supplier shall furnish either a hot-dip zinc coating in accordance with Specification A 153, Class C or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50.
4.3.3 Cadmium Plating—Cadmium plated washers shall be cadmium plated by electrodeposition and yellow chromate treated in accordance with Federal Specification QQ-P-416, Type II, Class 3.
4.3.4 Zinc Plating, Electroplated and Mechanically Deposited:
4.3.4.1 When zinc plated washers are required, the purchaser shall specify the zinc plating process such as “electroplating” or “mechanical plating” or “no preference”.
4.3.4.2 When “electroplating” is specified, the washer shall be zinc plated by electrodeposition in accordance with Specification B 633, Class Fe/Zn 5, Type II unless otherwise specified. See Specification B 633 for other thickness classes and finish types.
4.3.4.3 When “mechanical plating” is specified, the washer shall be zinc plated by mechanical deposition in accordance with Specification B 695, Class 5, Type II unless otherwise specified. See Specification B 695 for other thickness classes and finish types.
4.3.4.4 When “no preference” is specified, the supplier, at his option, shall furnish either an electroplated finish in accordance with Specification B 633, Class Fe/Zn 5, Type II, or a mechanically plated finish in accordance with Specification B 695, Class 5, Type II.
4.3.5 Phosphate Coating—Phosphate coated washers shall be coated in accordance with Military Specification DOD-P-16232, Type Z, Class 2.
4.3.6 Other Coatings—Other protective coatings shall be as specified by the purchaser.

5. Chemical Composition
5.1 Composition Limits:
5.1.1 The washers shall be steel, and unless otherwise specified, shall have no specified chemical composition requirements.
5.1.2 When required, the washers shall be specified to conform to specific chemical requirements.
5.2 Manufacturer’s Analysis—When specific chemical requirements have been specified and test reports are required, the manufacturer shall make individual analyses of randomly selected washers from the product to be shipped and report the results to the purchaser. In addition, if heat and lot identities have been maintained, the analysis of the raw material from which the fasteners have been manufactured shall, at the option of the manufacturer, be reported instead of product analysis.
5.3 Product Analysis—When specific chemical requirements have been specified, the purchaser reserves the right to conduct product analyses on the finished washers or request the manufacturer to conduct product analyses. The chemical composition thus determined shall conform to the specified requirements subject to the standard permissible variations for product analysis in Specification A 568/A 568M for washers punched from sheet; and Specification A 29 for washers machined from bar and tubing, or forged.

6. Mechanical Properties
6.1 Unless otherwise specified, the washers are not furnished to mechanical requirements.
6.2 When required and specified, the washers shall conform to the specified hardness.

7. Dimensions, Mass, and Permissible Variations
7.1 Standard Dimensions—Unless otherwise specified, the dimension shall be in accordance with ANSI B18.22.1, Tables 1A and Tables 1B for Type A washers. Where narrow (N) and wide (W) washers are provided for, the narrow type shall be furnished unless otherwise specified.
7.2 Non-Standard Dimensions—Other washers covered by this specification are generally referred to as US standard washers, SAE washers, light steel washers, riveting washers, fender washers, machinery bushing washers, machine screw washers, and similar designations. When specified, washers shall be furnished to these standards or shall be manufactured to the purchaser’s drawing requirements.
7.3 Parallelism—Washer faces shall be parallel within 0.005 in.
7.4 Flatness:
7.4.1 Washer faces shall be flat within the following requirements:

<table>
<thead>
<tr>
<th>Outside Diameter, inches</th>
<th>Out of Flat, inches, maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.500 and less</td>
<td>0.007</td>
</tr>
<tr>
<td>0.5625 through 1.250</td>
<td>0.010</td>
</tr>
<tr>
<td>over 1.250</td>
<td>0.015</td>
</tr>
</tbody>
</table>

7.4.2 Flatness shall be measured by laying a flat or concave side of the washer, if there is one, on a surface plate (so it rests on its outside diameter), and measuring the maximum difference in height of the other side above the surface plate. If both sides are convex, or if the washer is bent, both sides could be checked in the same manner, but:
7.4.2.1 A convex side will rest on the edge of the hole.
7.4.2.2 A bent (curved) washer shall be restrained to minimize the readings.

7.5 Runout—The runout of the outside diameter relative to the inside diameter shall not exceed a full indicator movement (FIM) equal to the inside diameter tolerance of ANSI B18.22.1.

8. Workmanship, Finish, and Appearance
8.1 Within the limits of good manufacturing practice, the washers shall be smooth, and free of burrs, loose scale, sharp edges, and other injurious imperfections.
8.2 Where protective finishes are specified, the requirements for the finish shall be in accordance with the requirements of the referenced specification.

9. Number of Tests and Retests

9.1 When mechanical requirements are specified, and for coating weight or thickness of coated products, the number of tests for each requirement specified shall be in accordance with Guide F 1470, sampling level for the detection process; unless the purchaser and manufacturer have mutually agreed to use the prevention process. See Guide F 1470 on Selection of Sampling Plans.

9.2 If the failure of a test specimen is due to improper preparation of the specimen or to incorrect testing technique, the specimen shall be discarded and another test specimen substituted.

10. Test Methods

10.1 Chemical Analysis—The chemical composition shall be determined by commercial test method. In the event of disagreement, chemical tests shall be made in accordance with Test Methods A 751.

10.2 Mechanical Tests—Hardness tests, when required, shall be performed in accordance with Test Methods F 606.

11. Inspection

11.1 The purchaser’s representative representing the purchaser shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the purchaser’s representative all reasonable facilities to satisfy that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser’s representative shall be made prior to shipment, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

12. Certification

12.1 Certificate of Compliance—When specified in the contract or purchase order, the manufacturer shall furnish certification that the product was manufactured and tested in accordance with this specification and conforms to all specified requirements.

12.2 Test Reports, Normal Inspection—When test reports are specified on the purchase order for normal inspection as provided for by 9.1, the manufacturer shall furnish a test report certified to be the last complete set of mechanical tests for each stock size in each shipment.

12.3 Test Reports, Individual Shipments—When shipment lot testing in accordance with 9.2 is specified in the contract or purchase order, the manufacturer shall furnish a test report showing the results of the tests required for each lot shipped.

13. Responsibility

13.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

14. Product Marking

14.1 Individual washers are not required to be marked.

15. Packaging and Package Marking

15.1 Packaging:

15.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

15.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

15.2 Package Marking:

15.2.1 Each shipping unit shall include or be plainly marked with the following information:

15.2.1.1 ASTM designation,

15.2.1.2 Size,

15.2.1.3 Name and brand or trademark of the manufacturer,

15.2.1.4 Number of pieces,

15.2.1.5 Purchase order number, and

15.2.1.6 Country of origin.

16. Keywords

16.1 carbon steel; plain; steel; washers

SUMMARY OF CHANGES

This section identifies the location of selected changes to this specification that have been incorporated since the –98 issue. For the convenience of the user, Committee F16 has highlighted those changes that may impact the use of this specification. This section may also include descriptions of the changes or reasons for the changes, or both.

(1) Added 3.2.8, providing for optional use of ASME B18.24.1, Part Identifying Number (PIN) Code System.
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Standard Specification for
Stainless Steel Socket Button and Flat Countersunk Head
Cap Screws

This standard is issued under the fixed designation F 879; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers the chemical and mechanical
requirements for stainless steel inch hexagon socket button
(SBHCS) and flat countersunk (SFHCS) head cap screws with
nominal thread 0.060 through 0.625 in. intended for use in
applications requiring general corrosion resistance.

1.2 The following three conditions are covered:

1.2.1 Austenitic alloy group 1 AF in an annealed condition
at 85 ksi maximum,

1.2.2 Austenitic alloy group 1 CW in a cold-worked condi-
tion at 80 ksi minimum, and

1.2.3 Austenitic alloy group 1 condition CW1 in a cold
worked condition at 102 ksi minimum.

1.3 The following precautionary caveat pertains only to the
test method portion, Section 12, of this specification: This
standard does not purport to address all of the safety concerns,
if any, associated with its use. It is the responsibility of the user
of this standard to establish appropriate safety and health
practices and determine the applicability of regulatory limi-
tations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
A 262 Practices for Detecting Susceptibility to Intergranu-
lar Attack in Austenitic Stainless Steels
A 342 Test Methods for Permeability of Feebly Magnetic
Materials
A 380 Practice for Cleaning, Descaling, and Passivation of
Stainless Steel Parts, Equipment, and Systems
A 555/A555M Specification for General Requirements for
Stainless Steel Wire and Wire Rods
A 751 Test Methods, Practices, and Terminology for
Chemical Analysis of Steel Products

1 This specification is under the jurisdiction of ASTM Committee F16 on
Fasteners and is the direct responsibility of Subcommittee F16.04 on Nonferrous
Fasteners.
published as F 879 – 86. Last previous edition F 879 – 02.
2 Annual Book of ASTM Standards, Vol 01.03.
3 Annual Book of ASTM Standards, Vol 03.04.

A 967 Specification for Chemical Passivation Treatments for
Stainless Steel Parts
D 3951 Practice for Commercial Packaging
E 18 Test Methods for Rockwell Hardness and Rockwell
Superficial Hardness of Metallic Materials
E 92 Test Method for Vickers Hardness of Metallic Mat-
erials
E 384 Test Method for Microhardness of Materials
F 593 Specification for Stainless Steel Bolts, Hex Cap,
Screws, and Studs
F 606 Test Methods for Determining the Mechanical Prop-
eties of Externally and Internally Threaded Fasteners,
Washers, and Rivets
F 788/F 788M Specification for Surface Discontinuities of
Bolts, Screws, and Studs, Inch and Metric Series
F 1470 Guide for Fastener Sampling for Specified Mechani-
ical Properties and Performance Inspection

2.2 ASME Standard:
B 18.3 Socket Cap, Shoulder and Set Screws (Inch Series)

3. Classification

3.1 The designation of the alloy group and condition of this
specification shall be consistent with the stainless steel desig-
nations in Specification F 593.

3.2 The austenitic stainless steel socket screw shall be
designated F 879 Group 1 Condition AF, F 879 Group 1
Condition CW, or F879 Group 1 Condition CW1.

4. Ordering Information

4.1 Orders for material under this specification shall include
the following information:

4.1.1 Quantity (number of pieces of each item).

4.1.2 Name of the screw, SBHCS or SFHCS.

4 Available from Global Engineering Documents, 15 Inverness Way East,
Englewood, CO 80112.
4.1.3 Dimensions, including nominal thread designation, thread pitch, and nominal screw length (inches). A standard part number may be used for this definition.

4.1.4 Alloy group and condition (Group 1 AF, Group 1 CW, Group 1 CW1).

4.1.5 Certification, if required (see Section 15).

4.1.6 ASTM specification and year of issue.

4.1.7 Any special or supplemental requirements (see Supplementary Requirements S1 through S6).

5. Materials and Manufacture

5.1 Screws shall be formed by upsetting or extruding, or both.

5.2 Screws shall be roll threaded.

5.3 Heat Treatment—Austenitic alloys Condition AF screws, following manufacture, shall be annealed by heating to 1900 ± 50°F to obtain maximum corrosion resistance and minimum permeability. The screws shall be held for a sufficient time at temperature, then cooled at a rate sufficient to prevent precipitation of the carbide and provide the properties specified in Table 1.

5.4 When Condition CW or CW1 is specified, the austenitic alloys shall be annealed as specified in 5.3, generally by the raw material manufacturer, then cold worked to develop specific properties.

6. Chemical Composition

6.1 It is the intent of this specification that screws shall be ordered by alloy condition. The chemical composition of the screws shall conform to the requirements of Table 2.

6.2 Unless otherwise specified in the inquiry and purchase order (see Supplementary Requirement S2), the choice of stainless steel used shall be that of the fastener manufacturer as determined by his fabrication methods and material availability. The specific stainless steel used by the manufacturer shall be clearly identified on all certification required in the purchase order and shall have a chemical composition conforming to the limits specified in Table 2.

6.3 When chemical analysis is performed by the purchaser using finished fasteners, the chemical composition obtained shall conform to the limits specified in Table 2 for the specific alloy. Chemical composition shall conform to the tolerances specified in Specification A 555.

6.3.1 In the event of a discrepancy, a referee analysis of the samples for each lot as specified in 12.1 shall be made in accordance with 11.3.1.

7. Mechanical Properties

7.1 The finished screws shall conform to the mechanical requirements specified in Table 1.

7.2 Screws having a nominal length equal to or greater than three diameters shall be tensile tested full size and shall meet the full size breaking strength requirements specified in Table 3. Tensile failures through the head are acceptable providing the load requirements are satisfied.

7.3 Screws that are too short (lengths less than specified in 7.2 or that have insufficient threads for tension testing) shall not be subject to tension tests, but shall conform to the hardness requirements of Table 1.

8. Corrosion Resistance Requirements

8.1 Carbide Precipitation:

8.1.1 Rod, bar, and wire in the austenitic alloy group 1 used to make fasteners in accordance with this specification shall be capable of passing the test for susceptibility to intergranular corrosion as specified in Practice E of Practices A 262.

8.1.2 As stated in Practices A 262, samples may be subjected to the faster and more severe screening test in accordance with Practice A. Failing Practice A, specimens shall be tested to Practice E and be considered satisfactory if passing Practice E.

9. Dimensions

9.1 Unless otherwise specified, the dimensions shall conform to the requirements of ASME B18.3.

10. Workmanship and Finish

10.1 Surface Treatment—Unless otherwise specified, screws shall be cleaned, descaled, and passivated in accordance with Practice A 380 or Specification A 967 at the option of the manufacturer.

10.2 Surface Discontinuities:

10.2.1 The surface discontinuities for these products shall conform to Specification F 788/F 788M and the additional limitations specified herein.

10.2.1.1 Forging defects that connect the socket to the periphery of the head are not permissible. Defects originating on the periphery and with a traverse indicating a potential to intersect are not permissible. Other forging defects are permissible provided those located in the bearing area, fillet, and top surfaces shall not have a depth exceeding 0.03 D or 0.005 in. whichever is greater. For peripheral discontinuities, the maximum depth may be 0.06 D (see Fig. 1).

10.2.1.2 Forging defects located in the socket wall within 0.1 times the actual key engagement, T, from the bottom of the

---

**TABLE 1 Mechanical Property Requirements**

<table>
<thead>
<tr>
<th>Alloy Condition</th>
<th>Full Size Product Tests</th>
<th>Machined Specimen Tests</th>
<th>Core Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tensile Strength ksi</td>
<td>Extension</td>
<td>Tensile Strength ksi</td>
</tr>
<tr>
<td>AF</td>
<td>85 max</td>
<td>0.6D</td>
<td>85 max</td>
</tr>
<tr>
<td>CW</td>
<td>80 min</td>
<td>0.4D</td>
<td>80 min</td>
</tr>
<tr>
<td>CW1</td>
<td>102 min</td>
<td>0.4D</td>
<td>87 min</td>
</tr>
</tbody>
</table>

---

*Actual full-size testing of condition CW and CW1 may result in decreased tensile strength because of the head configuration (see Table 3). For fasteners with nominal thread diameters larger than 0.625 in., the mechanical properties shall be agreed upon between the user and manufacturer.

*Core hardness is only required when full-size product testing cannot be accomplished.

*D denotes nominal thread size.
socket are not permissible. Discontinuities located elsewhere in the socket shall not have a length exceeding 0.25 $T$, or a maximum depth of 0.03 $D$, to exceed 0.005 in. (see Fig. 2).

10.2.1.3 Seams in the shank shall not exceed a depth of 0.03 $D$ or 0.008 in. whichever is greater.

10.2.1.4 No transverse discontinuities shall be permitted in the head-to-shank fillet area.

10.2.1.5 Threads shall have no laps at the root or on the flanks, as shown in Fig. 3. Laps are permitted at the crests (Fig. 3(C)) that do not exceed 25% of the basic thread depth, and on the flanks outside the pitch cylinder. Longitudinal seams rolled beneath the root of the thread and across the crests of the threads are acceptable within the limits of 10.2.1.3.

11. Number of Tests

11.1 The requirements of this specification shall be met in continuous mass production for stock and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of fasteners are not ordinarily necessary. A record of the individual heat of steel in each lot shall be maintained. The containers shall be coded to permit identification of the lot.
11.2 When specified in the purchase order, the manufacturer shall furnish a test report of the last complete set of chemical analysis and mechanical tests for each stock size in each shipment.

11.3 When tests of individual shipments are required, Supplementary Requirement S1 must be specified in the inquiry and order.

11.3.1 When the purchaser does not specify the sampling plan and basis of acceptance, the following shall apply:

11.3.1.1 The lot, for purposes of selecting samples, shall consist of all products offered for inspection and testing at one time that are of the same type, style, nominal diameter, thread pitch, nominal length, material, condition, and surface finish.

11.3.1.2 From each lot, samples shall be selected at random and tested for each requirement in accordance with the following:

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and less</td>
<td>1</td>
</tr>
<tr>
<td>Over 800 to 8000, incl</td>
<td>2</td>
</tr>
<tr>
<td>Over 8000 to 22 000, incl</td>
<td>3</td>
</tr>
<tr>
<td>Over 22 000</td>
<td>5</td>
</tr>
</tbody>
</table>

11.3.1.3 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be retested for the requirement(s) in which it failed. All of the additional samples shall conform to the specification, or the lot shall be rejected.

11.3.1.4 If the failure of a test specimen is due to improper preparation of the specimen or an incorrect testing technique, the specimen shall be discarded and another test specimen submitted.

11.4 Corrosion Resistance Tests:

11.4.1 Unless otherwise specified, inspection for corrosion resistance shall be in accordance with the manufacturer's standard quality control practices. No specific method of inspection is required but the screws shall be produced from suitable raw material and manufactured by properly controlled practices to maintain resistance to corrosion. When corrosion tests are required, Supplementary Requirement S5 must be specified in the inquiry and order, except as noted in 11.4.2.

11.4.2 Products that have been hot worked shall be solution annealed and tested to determine freedom from precipitated carbides. Not less than one corrosion test shall be made from each lot. Corrosion tests shall be performed in accordance with Practices A 262, Practices A or E as applicable.

12. Test Methods

12.1 Chemical Analysis—The chemical composition shall be determined in accordance with Test Method A 751.

12.1.1 The fastener manufacturer may accept the chemical analysis of each heat of raw material purchased and reported on the raw material certification furnished by the raw material producer. The fastener manufacturer is not required to do any further chemical analysis testing provided that precise heat lot traceability has been maintained throughout the manufacturing process on each lot of fasteners produced and delivered.

12.2 Mechanical Tests:

12.2.1 Screws tested for axial strength, screw extension, or hardness shall be tested in accordance with the methods described in Test Methods F 606 and of this specification. The hardness shall be determined using Test Methods E 18, E 92, or E 384 as appropriate. Fracture in the CW or CW1 condition may occur at the head/shank juncture (see Note 1 of Table 3) due to the part design.

12.2.2 Machined test specimens tested for tensile strength, yield strength at 0.2 % offset and elongation, shall be tested in accordance with the methods described in Test Methods F 606.

12.2.3 Extension Test—An extension test is applicable only to full-size products. The overall length of the test specimen, \( L_1 \), shall be measured within \( \pm 0.005 \) in. The head-end reference surface for length measurement may be the bottom of the hex socket for measuring purposes. The specimen shall be assembled into a threaded adapter to a depth of one nominal diameter, then axial tensile shall be tested in accordance with 12.2.1 to failure. The two broken pieces shall be fitted closely together and the overall length, \( L_2 \), measured again. The total extension shall be computed by subtracting the original overall length from the following fracture (Fig. 4). The product is
acceptable when the extension equals or exceeds the minimum value for extension specified in Table 1.

12.3 Corrosion Resistance—When specified on the purchase order or inquiry, corrosion tests to determine freedom from precipitated carbides shall be performed in accordance with Practices A 262, Practice A or E as applicable.

13. Inspection

13.1 If the inspection described in 13.2 is required by the purchaser, it shall be specified in the inquiry, order, or contract.

13.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy that the material is being furnished in accordance with this specification. All tests and inspection required by the specification that are requested by the purchaser’s representative and purchase order shall be made prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the work.

14. Rejection and Rehearing

14.1 Screws that fail to conform to the requirements of this specification may be rejected by the purchaser. Rejection shall be reported to the supplier promptly and in writing. In case of dissatisfaction with the results of tests or inspection authorized by the purchaser, the supplier may make claim for a rehearing.

15. Certification

15.1 Test Report—The manufacturer shall maintain on file for a period of 5 years, the original test report, including a copy of the certified chemical analysis of the heat of material used and the results of the required testing for the lot of fasteners.

15.2 Manufacturer’s Certificate of Conformance—The manufacturer shall maintain on file for a period of 5 years, a certificate indicating that the lot of fasteners was manufactured and tested in accordance with this specification and conforms to all specified requirements.

15.3 When requested by the purchaser, submission of copies of the test report, manufacturer’s certificate or an extension of the 5-year document retention period shall be performed as agreed between the manufacturer and the purchaser at the time of the inquiry or order.

16. Packaging and Package Marking

16.1 Packaging:

16.1.1 The manufacturer shall employ such methods of packaging the screws as may be reasonably required to ensure their receipt by the purchaser in a satisfactory condition. Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

16.1.2 When special packaging requirements are required by the purchaser, they shall be defined at the time of inquiry and order.

16.2 Package Marking—Each shipping unit shall include or be plainly marked with the following information:

16.2.1 ASTM specification,

16.2.2 Alloy condition,

16.2.3 Alloy number,

16.2.4 Size,

16.2.5 Name and brand or trademark of the manufacturer,

16.2.6 Country of origin,

16.2.7 Number of pieces, and

16.2.8 Purchase order number.

17. Keywords

17.1 corrosion resistant; stainless steel; socket button head cap screws; socket flat countersunk head cap screws
SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry and order (see 4.1.7). Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Shipment Lot Testing
   S1.1 When Supplementary Requirement S1 is specified on the order, the manufacturer shall make sample tests on the individual lots for shipment to ensure that the product conforms to the specified requirements.
   S1.2 The manufacturer shall make an analysis of a randomly selected finished fastener from each lot of product to be shipped. Heat or lot control shall be maintained. The analysis of the starting material from which the fasteners have been manufactured may be reported in place of the product analysis.
   S1.3 The manufacturer shall perform mechanical property tests in accordance with this specification and Guide F 1470 on the individual lots for shipment.
   S1.4 The manufacturer shall furnish a test report for each lot in the shipment showing the actual results of the chemical analysis and mechanical property tests performed in accordance with Supplementary Requirement S1.

S2. Alloy Control
   S2.1 When Supplementary Requirement S2 is specified on the inquiry and order, the manufacturer shall supply that stainless steel specified on the customer’s order with no substitutions permitted without written permission by the purchaser.

S3. Permeability
   S3.1 When Supplementary Requirement S3 is specified on the inquiry and order, the permeability of Condition AF screws shall not exceed 1.05 at 100 oersteds when determined by Test Method A 342. Screws in Condition CW or CW1 may not be capable of meeting permeability and strength requirements simultaneously. Consultation with the raw material manufacturer should be considered for critical permeability requirements.

S4. Identification
   S4.1 When Supplementary Requirement S4 is specified on the inquiry and order for nominal sizes 1/4 (0.250) in. and larger, the fasteners shall be marked with the manufacturer’s insignia. The manufacturer’s identification insignia shall be of the design, placed on the side or top of the head and known and recognizable to the purchaser. The insignia shall be readable at no greater than 10x magnification.

S5. Corrosion Resistance Tests
   S5.1 When Supplementary Requirement S5 is specified on the inquiry and order, corrosion test(s) shall be performed as agreed between the manufacturer and the purchaser at the time of the inquiry or order.

S6. Passivation
   S6.1 When Supplementary Requirement S6 is specified on the inquiry and order, the finished product shall be passivated in accordance with Specification A 380.
Designation: F 879M – 02a
METRIC

Standard Specification for Stainless Steel Socket Button and Flat Countersunk Head Cap Screws [Metric]¹

This standard is issued under the fixed designation F 879M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers the chemical and mechanical requirements for stainless steel metric hexagon socket button (SBHCS) and flat countersunk (SFHCS) head cap screws with nominal thread M 3 through M 20 intended for use in applications requiring general corrosion resistance.

1.2 The following three property classes are covered:

1.2.1 Austenitic Class A 1-50 in an annealed condition at 585 MPa maximum,

1.2.2 Austenitic Class A1–55 in a cold worked condition at 550 MPa minimum, and

1.2.3 Austenitic Class A 1-70 in a cold-worked condition at 700 MPa minimum.

1.3 The following hazard caveat pertains only to Section 12, Test Methods: This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels²

A 342 Test Methods for Permeability of Feebly Magnetic Materials³

A 380 Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems²

A 555/A555M Specification for General Requirements for Stainless Steel Wire and Wire Rods²

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products²

A 967 Specification for Chemical Passivation Treatments for Stainless Steel Parts²

D 3951 Practice for Commercial Packaging⁴

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials⁵

E 92 Test Method for Vickers Hardness of Metallic Materials⁵

E 384 Test Method for Microhardness of Materials⁵


F 738M Specification for Stainless Steel Metric Bolts, Screws, and Studs⁶

F 788/F788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series⁶

F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection⁶

2.2 ASME Standards:

B 18.3.4M Hexagon Socket Button Head Cap Screws (Metric Series)⁷

B 18.3.5M Hexagon Socket Flat Countersunk Head Cap Screws (Metric Series)⁷

3. Classification

3.1 The designation of the property class and conditions of this specification shall be consistent with the stainless steel designations in Specification F 738M.


4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Quantity (number of pieces of each item).

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¹ This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.04 on Nonferrous Fasteners.


³ Annual Book of ASTM Standards, Vol 01.03.

⁴ Annual Book of ASTM Standards, Vol 03.01.

⁵ Available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112.

⁶ Available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112.
4.1.2 Name of the screw, SBHCS or SFHCS.
4.1.3 Dimensions, including nominal thread designation, thread pitch, and nominal screw length (millimetres). A standard part number may be used for this definition.
4.1.5 Certification, if required (see Section 15).
4.1.6 ASTM specification and year of issue.
4.1.7 Any special or supplemental requirements (see Supplementary Requirements S1 through S3).

5. Materials and Manufacture

5.1 Screws shall be formed by upsetting or extruding, or both.
5.2 Screws shall be roll threaded.
5.3 Heat Treatment—Austenitic alloys Class A 1-50 screws, following manufacture, shall be annealed by heating to 1040 ± 30°C to obtain maximum corrosion resistance and minimum permeability. The screws shall be held for a sufficient time at temperature, then cooled at a rate sufficient to prevent precipitation of the carbide and provide the properties specified in Table 1.
5.4 When Property Class A1-55 or A1-70 is specified, the austenitic alloys shall be annealed as specified in 5.3, generally by the raw material manufacturer, then cold worked to develop specific properties.

6. Chemical Composition

6.1 It is the intent of this specification that screws shall be ordered by property class. The chemical composition of the screws shall conform to the requirements of Table 2.
6.2 Unless otherwise specified in the inquiry and purchase order (see Supplementary Requirement S2), the choice of stainless steel used shall be that of the fastener manufacturer as determined by his fabrication methods and material availability. The specific stainless steel used by the manufacturer shall be clearly identified on all certification required in the purchase order and shall have a chemical composition conforming to the limits specified in Table 2.
6.3 When chemical analysis is performed by the purchaser using finished fasteners, the chemical composition obtained shall conform to the limits specified in Table 2 for the specific alloy. Chemical composition shall conform to the tolerances specified in Specification A 555/A 555M.
6.3.1 In the event of a discrepancy, a referee analysis of the samples for each lot as specified in 12.1, shall be made in accordance with 11.3.

7. Mechanical Properties

7.1 The finished screws shall conform to the mechanical requirements specified in Table 1.
7.2 Screws having a nominal length equal to or greater than three diameters shall be tensile tested full size and shall meet the full size breaking strength requirements specified in Table 3. Tensile failures through the head are acceptable providing the load requirements are satisfied.
7.3 Screws that are too short (lengths less than specified in 7.2 or that have insufficient threads for tension testing) shall not be subject to tension tests, but shall conform to the hardness requirements of Table 1.

8. Corrosion Resistance Requirements

8.1 Carbide Precipitation:
8.1.1 Austenitic alloy rod, bar, and wire used to make fasteners in accordance with this specification shall be capable of passing the test for susceptibility to intergranular corrosion as specified in Practice E of Practice A 262.
8.1.2 As stated in Practices A 262, samples may be subjected to the faster and more severe screening test in accordance with Practice A. Failing Practice A, specimens shall be tested to Practice E and be considered satisfactory if passing Practice E.
8.1.3 If the fasteners pass the requirements of 8.1.1, they shall be considered acceptable. If they fail, they shall be tested in accordance with Practice C of Practices A 262 and shall show a corrosion rate not exceeding 0.05 mm/month.

9. Dimensions

9.1 Unless otherwise specified, the dimensions shall conform to the requirements of ASME B 18.3.4M or ASME B 18.3.5M, as specified.

10. Workmanship, Finish, and Appearance

10.1 Surface Treatment—Unless otherwise specified, screws shall be cleaned, descaled and passivated in accordance with Practice A380 or Specification A 967 at the option of the manufacturer.
10.2 Surface Discontinuities:
10.2.1 The surface discontinuities for these products shall conform to Specification F 788/F 788M and the additional limitations specified herein.
10.2.1.1 Forging defects that connect the socket to the periphery of the head are not permissible. Defects originating on the periphery and with a traverse indicating a potential to...

### TABLE 1 Mechanical Property Requirements

<table>
<thead>
<tr>
<th>Property Class</th>
<th>Nominal Thread Diameter&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Full Size Product Tests</th>
<th>Machined Specimen Tests</th>
<th>Core Hardness&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tensile Strength, MPa</td>
<td>Minimum Extension&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Tensile Strength, MPa</td>
</tr>
<tr>
<td>A1-50</td>
<td>M3–M20</td>
<td>585 max</td>
<td>0.6D</td>
<td>585 max</td>
</tr>
<tr>
<td>A1–55</td>
<td>M3–M20</td>
<td>550 min</td>
<td>0.4D</td>
<td>550 min</td>
</tr>
<tr>
<td>A1–70</td>
<td>M3–M20</td>
<td>700 min</td>
<td>0.4D</td>
<td>600 min</td>
</tr>
</tbody>
</table>

<sup>a</sup> Actual full-size testing of Class A1–55 and A1–70 may result in decreased tensile strength because of the head configuration (see Table 3). For fasteners with nominal thread diameters larger than M20, the mechanical properties shall be agreed upon between the user and manufacturer.

<sup>b</sup> Core hardness is only required when full-size product tensile testing cannot be accomplished.

<sup>c</sup> D denotes nominal thread size.
intersect are not permissible. Other forging defects are permissible provided those located in the bearing area, fillet, and top surfaces shall not have a depth exceeding 0.03D or 0.13 mm, whichever is greater. For peripheral discontinuities, the maximum depth may be 0.06D (see Fig. 1).

10.2.1.2 Forging defects located in the socket wall within 0.1 times the actual key engagement, T, from the bottom of the socket are not permissible. Discontinuities located elsewhere in the socket shall not have a length exceeding 0.25T, or a maximum depth of 0.03 D or 0.13 mm, whichever is greater. For peripheral discontinuities, the maximum depth may be 0.06 D (see Fig. 1).

10.2.1.3 Seams in the shank shall not exceed a depth of 0.03D or 0.2 mm, whichever is greater.

10.2.1.4 No transverse discontinuities shall be permitted in the head-to-shank fillet area.

10.2.1.5 Threads shall have no laps at the root or on the flanks, as shown in Fig. 3. Laps are permitted at the crests (Fig. 3(c)) that do not exceed 25% of the basic thread depth, and on the flanks outside the pitch cylinder. Longitudinal seams rolled beneath the root of the thread and across the crests of the threads are acceptable within the limits of 10.2.1.3.

11. Number of Tests

11.1 The requirements of this specification shall be met in continuous mass production for stock and the manufacturer shall make sample inspection to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of fasteners are not ordinarily necessary. A record of the individual heat of steel in each lot shall be maintained. The containers shall be coded to permit identification of the lot.

11.2 When specified in the purchase order, the manufacturer shall furnish a test report of the last complete set of chemical

---

**TABLE 2 Chemical Requirements**

<table>
<thead>
<tr>
<th>UNS Designation</th>
<th>Alloy</th>
<th>Composition, % maximum except as shown</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Carbon</td>
</tr>
<tr>
<td>S30400</td>
<td>304</td>
<td>0.08</td>
</tr>
<tr>
<td>S30403</td>
<td>304L</td>
<td>0.030</td>
</tr>
<tr>
<td>S30500</td>
<td>305</td>
<td>0.12</td>
</tr>
<tr>
<td>S38400</td>
<td>384</td>
<td>0.08</td>
</tr>
<tr>
<td>S38430</td>
<td>18–9LW</td>
<td>0.10</td>
</tr>
<tr>
<td>S30433</td>
<td>302HQ</td>
<td>0.03</td>
</tr>
<tr>
<td>S31600</td>
<td>316</td>
<td>0.08</td>
</tr>
<tr>
<td>S31603</td>
<td>316L</td>
<td>0.03</td>
</tr>
</tbody>
</table>

**TABLE 3 Breaking Strength Values for Full Size Fasteners**

**NOTE 1**—Breaking loads are based on tensile stress area and strengths of 585 MPa max for A1–50, 550 MPa for A1–55, and 700 MPa min A1–70. The minimum loads for property classes A1–55 and A1–70 are reduced by 20% to allow for the head critical nature of these configurations. See Note A in Table 1. Actual strength of the threaded section, if size permits, may be determined by removing the head and testing the threaded section as a stud.

<table>
<thead>
<tr>
<th>Nominal Size and Thread Pitch</th>
<th>Stress Area, mm²</th>
<th>Property Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stress Area, mm²</td>
<td>A1–50</td>
</tr>
<tr>
<td></td>
<td>Stress Area, mm²</td>
<td>kN, max</td>
</tr>
<tr>
<td>M3 × 0.5</td>
<td>5.03</td>
<td>2.94</td>
</tr>
<tr>
<td>M4 × 0.7</td>
<td>8.78</td>
<td>5.14</td>
</tr>
<tr>
<td>M5 × 0.8</td>
<td>14.2</td>
<td>8.30</td>
</tr>
<tr>
<td>M6 × 1.0</td>
<td>20.1</td>
<td>11.8</td>
</tr>
<tr>
<td>M8 × 1.25</td>
<td>36.6</td>
<td>21.4</td>
</tr>
<tr>
<td>M10 × 1.5</td>
<td>58.0</td>
<td>33.9</td>
</tr>
<tr>
<td>M12 × 1.75</td>
<td>84.3</td>
<td>49.3</td>
</tr>
<tr>
<td>M14 × 2.0</td>
<td>115.0</td>
<td>67.5</td>
</tr>
<tr>
<td>M16 × 2.0</td>
<td>157.0</td>
<td>91.7</td>
</tr>
<tr>
<td>M20 × 2.5</td>
<td>245.0</td>
<td>143</td>
</tr>
</tbody>
</table>

---

FIG. 1 Head Discontinuities (See 10.2.1)

FIG. 2 Socket Discontinuities (See 10.2.1)
analysis and mechanical tests for each stock size in each shipment.

11.3 When tests of individual shipments are required, Supplementary Requirement S1 must be specified in the inquiry and order.

11.3.1 When the purchaser does not specify the sampling plan and basis of acceptance, the following shall apply:

11.3.1.1 The lot, for purposes of selecting samples, shall consist of all products offered for inspection and testing at one time, that are of the same type, style, nominal diameter, thread pitch, nominal length, material, property class, and surface finish.

11.3.1.2 From each lot, samples shall be selected at random and tested for each requirement in accordance with the following:

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and less</td>
<td>1</td>
</tr>
<tr>
<td>Over 800 to 8000, incl</td>
<td>2</td>
</tr>
<tr>
<td>Over 8000 to 22,000, incl</td>
<td>3</td>
</tr>
<tr>
<td>Over 22,000</td>
<td>5</td>
</tr>
</tbody>
</table>

11.3.1.3 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be retested for the requirement(s) in which it failed. All of the additional samples shall conform to the specification or the lot shall be rejected.

11.3.1.4 If the failure of a test specimen is due to improper preparation of the specimen or an incorrect testing technique, the specimen shall be discarded and another test specimen submitted.

11.4 Corrosion Resistance Tests:

11.4.1 Unless otherwise specified, inspection for corrosion resistance shall be in accordance with the manufacturer’s standard quality control practices. No specific method of inspection is required but the screws shall be produced from suitable raw material and manufactured by properly controlled practices to maintain resistance to corrosion. When corrosion tests are required, Supplementary Requirement S4 must be specified in the inquiry and order, except as noted in 11.4.2.

11.4.2 Products that have been hot worked shall be solution annealed and tested to determine freedom from precipitated carbides. Not less than one corrosion test shall be made from each lot. Corrosion tests shall be performed in accordance with Practices A 262, Practices A or E as applicable.

12. Test Methods

12.1 Chemical Analysis—The chemical composition shall be determined in accordance with Test Method A 751.

12.1.1 The fastener manufacturer may accept the chemical analysis of each heat of raw material purchased and reported on the raw material certification furnished by the raw material producer. The fastener manufacturer is not required to do any further chemical analysis testing provided that precise heat lot traceability has been maintained throughout the manufacturing process on each lot of fasteners produced and delivered.

12.2 Mechanical Tests:

12.2.1 Screws tested for axial strength, screw extension, or hardness shall be tested in accordance with the methods described in Test Methods F 606M and 12.2.3 of this specification. The hardness shall be determined using Test Methods E 18, E 92, or E 384 as appropriate. Fracture in the A1-55 or A1-70 class may occur at the head/shank juncture (see Note 1 of Table 3) due to the part design.

12.2.2 Machined test specimens tested for tensile strength, yield strength at 0.2 % offset, and elongation shall be tested in accordance with the methods described in Test Methods F 606M.

12.2.3 Extension Test—An extension test is applicable only to full-size products. The overall length of the test specimen, $L_1$, shall be measured within ±0.12 mm. The head-end reference surface for length measurement may be the bottom of the hex socket for measuring purposes. The specimen shall be assembled into a threaded adapter to a depth of one nominal diameter, then axial tensile tested in accordance with 12.2.1 to failure. The two broken pieces shall be fitted closely together and the overall length, $L_2$, measured again. The total extension shall be computed by subtracting the original overall length.
from the length following fracture (Fig. 4). The product is acceptable when the extension equals or exceeds the minimum value for extension specified in Table 1.

12.3 Corrosion Resistance—When specified on the purchase order or inquiry, corrosion tests to determine freedom from precipitated carbides shall be performed in accordance with Practices A 262, Practice A or E as applicable.

13. Inspection

13.1 If the inspection described in 13.2 is required by the purchaser, it shall be specified in the inquiry, order, or contract.

13.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy that the material is being furnished in accordance with this specification. All tests and inspection required by the specification that are requested by the purchaser’s representative and purchase order shall be made prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the work.

14. Rejection and Rehearing

14.1 Screws that fail to conform to the requirements of this specification may be rejected by the purchaser. Rejection shall be reported to the supplier promptly and in writing. In case of dissatisfaction with the results of tests or inspection authorized by the purchaser, the supplier may make claim for a rehearing.

15. Certification

15.1 Test Report—The manufacturer shall maintain on file for a period of 5 years, the original test report, including a copy of the certified chemical analysis of the heat of material used and the results of the required testing for the lot of fasteners.

15.2 Manufacturer’s Certificate of Conformance—The manufacturer shall maintain on file for a period of 5 years, a certificate indicating that the lot of fasteners was manufactured and tested in accordance with this specification and conforms to all specified requirements.

15.3 When requested by the purchaser, submission of copies of the test report, manufacturer’s certificate or an extension of the 5-year document retention period shall be performed as agreed between the manufacturer and the purchaser at the time of the inquiry or order.

16. Product Marking

16.1 For nominal sizes M5 (5 mm) and larger, the A1-50 fasteners shall be marked “A1-50.” For nominal sizes M5 (5 mm) and larger, the A1-70 fasteners shall be marked “A1-70.” The A1–55 fasteners need not be marked with the property class designation. For all three property classes, the manufacturer’s identification insignia shall be placed on the side or top of the head and known and recognizable to the purchaser. The insignia shall be readable with no more than 10× magnification.

17. Packaging and Package Marking

17.1 Packaging:

17.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

17.1.2 When special packaging requirements are required by the purchaser, they shall be defined at the time of inquiry and order.

17.2 Package Marking—Each shipping unit shall include or be plainly marked with the following:

17.2.1 ASTM specification,
17.2.2 Property class symbol,
17.2.3 Alloy number,
17.2.4 Size,
17.2.5 Name and brand or trademark of the manufacturer,
17.2.6 Country of origin,
17.2.7 Number of pieces, and
17.2.8 Purchase order number.

18. Keywords

18.1 corrosion resistant; stainless steel; socket button head cap screws; socket flat countersunk head cap screws
SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry and order (see 4.1.6). Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Shipment Lot Testing

S1.1 When Supplementary Requirement S1 is specified on the order, the manufacturer shall make sample tests on the individual lots for shipment to ensure that the product conforms to the specified requirements.

S1.2 The manufacturer shall make an analysis of a randomly selected finished fastener from each lot of product to be shipped. Heat or lot control shall be maintained. The analysis of the starting material from which the fasteners have been manufactured may be reported in place of the product analysis.

S1.3 The manufacturer shall perform mechanical property tests in accordance with this specification and Guide F 1470 on the individual lots for shipment.

S1.4 The manufacturer shall furnish a test report for each lot in the shipment showing the actual results of the chemical analysis and mechanical property tests performed in accordance with Supplementary Requirements S1.

S2. Alloy Control

S2.1 When Supplementary Requirement S2 is specified on the inquiry and order, the manufacturer shall supply that stainless steel specified on the customer’s order with no group substitutions permitted without written permission by the purchaser.

S3. Permeability

S3.1 When Supplementary Requirement S3 is specified on the inquiry and order, the permeability of Property Class A1-50 screws shall not exceed 1.05 at 100 oersteds when determined by Test Method A 342. Screws in Property Classes A1-55 or A1-70 may not be capable of meeting permeability and strength requirements simultaneously. Consultation with the raw material manufacturer should be considered for critical permeability requirements.

S4. Corrosion Resistance Tests

S4.1 When Supplementary Requirement S4 is specified on the inquiry and order, corrosion test(s) shall be performed as agreed between the manufacturer and the purchaser at the time of the inquiry or order.

S5. Passivation

S5.1 When Supplementary Requirement S5 is specified on the inquiry and order, the finished product shall be passivated in accordance with Specification A 380.
Standard Specification for Stainless Steel Socket-Set Screws

This standard is issued under the fixed designation F 880; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers the requirements for austenitic grade stainless steel socket-set screws (SSS) sizes 0.060 through 0.500 in., in two conditions, AF and CW.

1.2 The following hazards caveat pertains only to Test Method Section, Section 12 of this specification. This standard does not purport to address (all of) the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

NOTE 1—A complete metric companion to Specification F 880 has been developed—F 880M; therefore, no metric equivalents are shown in this specification.

2. Referenced Documents

2.1 ASTM Standards:
A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
A 342 Test Methods for Permeability of Feebly Magnetic Materials
A 380 Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
A 555/A 555M Specification for General Requirements for Stainless Steel Wire and Wire Rods
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A 967 Specification for Chemical Passivation Treatments for Stainless Steel Parts
D 3951 Practice for Commercial Packaging
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

3. Classification

3.1 The designation of the alloy group and condition for the two materials and conditions of this specification shall be consistent with the stainless steel designations in Specification F 593.

3.2 The austenitic stainless steel socket set screw shall be designated F 880 Group 1 Condition AF (solution annealed) or F 880 Group 1 Condition CW (cold worked).

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Quantity (number of screws);
4.1.2 Dimensions, including nominal thread designation, thread pitch, nominal screw length (inches) and point configuration. A standard part number may be used for this definition;
4.1.3 Name of the screw (SSS);
4.1.4 Condition AF/CW;
4.1.5 Surface finish, if required. If a finish other than passivation is required, it must be specified on the order or product standard;
4.1.6 ASTM specification and year of issue; and
4.1.7 Any special or supplemental requirements.

4.2 Example—50 000 pieces 0.250-20

5. Materials and Manufacture

5.1 The screw may be forged, formed, extruded, machined, or ground to meet the dimensional characteristics and performance requirements.

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1 This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.04 on Nonferrous Fasteners.
3 Annual Book of ASTM Standards, Vol 01.03.
4 Annual Book of ASTM Standards, Vol 03.04.
6 Annual Book of ASTM Standards, Vol 01.08.
7 Available from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.
5.2 Heat Treatment—Austenitic alloys Group 1 Condition
AF screw shall be annealed by heating to 1900 ± 50°F to
obtain maximum corrosion resistance and minimum perme-
ability. The screws shall be held for a sufficient time at
temperature, then cooled at a rate sufficient to prevent precipi-
tation of the carbide and provide the properties in accordance
with Table 1.

5.3 When condition CW is specified, the austenitic alloys
shall be annealed as specified in 5.2, generally by the raw
material manufacturer, and then cold worked to develop
specific properties.

6. Chemical Composition

6.1 The analysis of the screw material shall conform to the
chemical composition specified in Table 2.

6.2 Unless otherwise specified in the inquiry and purchase
order (see Supplementary Requirement S2), the choice of alloy
used shall be that of the fastener manufacturer as determined
by his fabrication methods and material availability. The
specific alloy used by the manufacturer shall be clearly
identified on all certification required in the purchase order and
shall have a chemical composition conforming to the limits
specified in Table 2.

6.3 When chemical analysis is performed by the purchaser
using finished fasteners representing each lot, the chemical
contents obtained shall conform to the limits specified in Table
2 for the specific alloy. Chemical composition shall conform to
the tolerances specified in Specification A 555/A 555M.

6.3.1 In the event of a discrepancy, a referee analysis of the
samples for each lot as specified in 12.1 shall be made in
accordance with 11.3.1.

7. Mechanical Properties

7.1 Socket-set screws, when subjected to a torque test in
accordance with 12.3.1, shall withstand application of the test
tightening torque specified in Table 1 without evidence of the
socket reaming or the screw bursting.

7.2 The hardness limits from 70 to 95 HRB (125 to 210
DPH) for Condition AF and 96 HRB to 33 HRC (216 to 327
DPH) for Condition CW shall be met as determined using Test
Methods E 18.

8. Corrosion Resistance Requirements

8.1 Carbide Precipitation:

8.1.1 Rod, bar, and wire in the austenitic alloy groups 1, 2,
and 3, except the free-machining grades, 303 and 303Se, used
to make fasteners in accordance with this specification shall be
able to pass the test for susceptibility to intergranular
corrosion as specified in Practice E of Practices A 262.

8.1.2 As stated in Practices A 262, samples may be sub-
jected to the faster and more severe screening test in accord-
ance with Practice A. Failing Practice A, specimens shall be
 tested to Practice E and be considered satisfactory if passing
Practice E.

9. Dimensions

9.1 Unless otherwise specified, the product shall conform to
the requirements of ASME B 18.3.

10. Workmanship, Finish, and Appearance

10.1 Surface Treatment—Unless otherwise specified,
screws shall be cleaned, descaled, and passivated in accordance
with Practice A 380 or Specification A 967 at the option of the
manufacturer.

10.2 Surface Discontinuities:

10.2.1 The surface discontinuities for these products shall
conform to Specification F 788/F 788M and the additional
limitations specified herein.

10.2.1.1 Processing cracks that connect the socket to the
periphery of the screw are not permissible. Defects originating
on the periphery with a traverse indicating a potential to
intersect are not permissible. For peripheral discontinuities,
the maximum depth may be 0.06 D.

11. Number of Tests

11.1 The requirements of this specification shall be met in
continuous mass production for stock and the manufacturer
shall make sample inspections to ensure that the product
conforms to the specified requirements. Additional tests of
individual shipments of fasteners are not ordinarily necessary.
A record of the individual heat of steel in each lot shall be
 maintained. The containers shall be coded to permit identifi-
cation of the lot.

<table>
<thead>
<tr>
<th>Nominal Screw Size</th>
<th>Shortest Nominal Screw Lengths Subject to Torque Testing</th>
<th>Test Torque, in.-lb, min</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cup and Flat Points, mm</td>
<td>Cone and Oval Points</td>
</tr>
<tr>
<td>0.060</td>
<td>0.109</td>
<td>0.125</td>
</tr>
<tr>
<td>0.073</td>
<td>0.125</td>
<td>0.141</td>
</tr>
<tr>
<td>0.086</td>
<td>0.125</td>
<td>0.141</td>
</tr>
<tr>
<td>0.099</td>
<td>0.141</td>
<td>0.156</td>
</tr>
<tr>
<td>0.112</td>
<td>0.141</td>
<td>0.172</td>
</tr>
<tr>
<td>0.125</td>
<td>0.188</td>
<td>0.188</td>
</tr>
<tr>
<td>0.138</td>
<td>0.172</td>
<td>0.203</td>
</tr>
<tr>
<td>0.164</td>
<td>0.188</td>
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<td>0.188</td>
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<tr>
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<tr>
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<td>0.375</td>
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</tr>
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</tr>
<tr>
<td>0.500</td>
<td>0.500</td>
<td>0.609</td>
</tr>
</tbody>
</table>

TABLE 1 Torsional Strength Requirements
11.2 When specified in the purchase order, the manufacturer shall furnish a test report of the last complete set of chemical analysis and mechanical tests for each stock size in each shipment.

11.3 When tests of individual shipments are required, Supplementary Requirement S1 must be specified in the inquiry and order.

11.3.1 When the purchaser does not specify the sampling plan and basis of acceptance, the following shall apply:

11.3.1.1 The lot, for purposes of selecting samples, shall consist of all products offered for inspection and testing at one time, that are of the same style, nominal diameter, thread pitch, nominal length, material type, and condition, and surface finish.

11.3.1.2 From each lot, samples shall be selected at random and tested for each requirement in accordance with the following:

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and less</td>
<td>1</td>
</tr>
<tr>
<td>Over 800 to 8000, incl</td>
<td>2</td>
</tr>
<tr>
<td>Over 8000 to 22 000, incl</td>
<td>3</td>
</tr>
<tr>
<td>Over 22 000</td>
<td>5</td>
</tr>
</tbody>
</table>

11.3.1.3 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be retested for the requirement(s) in which it failed. All of the additional samples shall conform to the specification or the lot shall be rejected.

11.3.1.4 If the failure of a test specimen is due to improper preparation of the specimen or an incorrect testing technique, the specimen shall be discarded and another test specimen submitted.

11.4 Corrosion Resistance Tests:

11.4.1 Unless otherwise specified, inspection for corrosion resistance shall be in accordance with the manufacturer’s standard quality control practices. No specific method of inspection is required but the screws shall be produced from suitable raw material and manufactured by properly controlled practices to maintain resistance to corrosion. When corrosion tests are required, Supplementary Requirement S4 must be specified in the inquiry and order except as noted in 11.4.2.

11.4.2 Products that have been hot worked shall be solution annealed and tested to determine freedom from precipitated carbides. Not less than one corrosion test shall be made from each lot. Corrosion tests shall be performed in accordance with Practices A 262, Practices A or E as applicable.

12. Test Methods

12.1 Chemical Analysis—The chemical composition shall be determined in accordance with Test Methods, Practices, and Terminology A 751.

12.2 The fastener manufacturer may accept the chemical analysis of each heat of raw material purchased and reported on the raw material certification furnished by the raw material producer. The fastener manufacturer is not required to do any further chemical analysis testing, provided that precise heat lot traceability has been maintained throughout the manufacturing process on each lot of fasteners produced and delivered.

12.3 Mechanical Tests:

12.3.1 For socket strength torque test, the test screw shall be assembled into a tapped hole of 5H tolerance class in a steel block (Fig. 1) until the face of the screw is flush with the top surface of the test block and the set screw bears against a firm base, such as a hardened screw installed from the opposite side of the block. The applicable hexagon key bit, in accordance with ASME B 18.3, shall be inserted to the full depth of the set screw socket and the test torque listed in Table 2 applied by means of a torque wrench. The screw shall be disassembled

<table>
<thead>
<tr>
<th>UNS Designation</th>
<th>Alloy</th>
<th>Composition, % maximum except as shown</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Carbon</td>
</tr>
<tr>
<td>S30300</td>
<td>303</td>
<td>0.15</td>
</tr>
<tr>
<td>S30303</td>
<td>303Se</td>
<td>0.15</td>
</tr>
<tr>
<td>S30400</td>
<td>304</td>
<td>0.08</td>
</tr>
<tr>
<td>S30403</td>
<td>304L</td>
<td>0.030</td>
</tr>
<tr>
<td>S30500</td>
<td>305</td>
<td>0.12</td>
</tr>
<tr>
<td>S38400</td>
<td>384</td>
<td>0.08</td>
</tr>
<tr>
<td>S20300</td>
<td>XM1</td>
<td>0.08</td>
</tr>
<tr>
<td>S30403</td>
<td>18–9LW</td>
<td>0.10</td>
</tr>
<tr>
<td>S30433</td>
<td>302HQ</td>
<td>0.03</td>
</tr>
</tbody>
</table>

* At the manufacturer’s option, determined only when intentionally added.

TABLE 2 Chemical Requirements

Fig. 1 Typical Torque Test Fixture
12.4 Corrosion Resistance—When specified on the purchase order or inquiry, corrosion tests to determine freedom from precipitated carbides shall be performed in accordance with Practices A 262, Practice A or E as applicable.

13. Inspection

13.1 If the inspection described in 13.2 is required by the purchaser, it shall be specified in the inquiry, order, or contract.

13.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy that the material is being furnished in accordance with this specification. All tests and inspection required by the specification that are requested by the purchaser’s representative and purchase order shall be made prior to shipment and shall be so conducted as not to interfere unnecessarily with the operation of the work.

14. Rejection and Rehearing

14.1 Screws that fail to conform to the requirements of this specification may be rejected by the purchaser. Rejection shall be reported to the supplier promptly and in writing. In case of dissatisfaction with the results of tests or inspection authorized by the purchaser, the supplier may make claim for a rehearing.

15. Certification

15.1 Test Report—The manufacturer shall maintain on file for a period of 5 years, the original test report, including a copy of the certified chemical analysis of the heat of material used and the results of the required testing for the lot of fasteners.

15.2 Manufacturer’s Certificate of Conformance—The manufacturer shall maintain on file for a period of 5 years, a certificate indicating that the lot of fasteners was manufactured and tested in accordance with this specification and conforms to all specified requirements.

15.3 When requested by the purchaser, submission of copies of the test report, manufacturer’s certificate or an extension of the 5 year document retention period shall be performed as agreed between the manufacturer and the purchaser at the time of the inquiry or order.

16. Packaging and Package Marking

16.1 Packaging:

16.1.1 The manufacturer shall employ such methods of packaging the screws as may be reasonably required to ensure their receipt by the purchaser in a satisfactory condition. Unless otherwise specified packaging shall be in accordance with Practice D 3951.

16.1.2 When special packaging requirements are required by the purchaser, they shall be defined at the time of inquiry and order.

16.2 Package Marking—Each shipping unit shall include or be plainly marked with the following:

16.2.1 ASTM specification,
16.2.2 Alloy condition,
16.2.3 Alloy number,
16.2.4 Size,
16.2.5 Name and brand or trademark of the manufacturer,
16.2.6 Country of origin,
16.2.7 Number of pieces, and
16.2.8 Purchase order number.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry and order (see 4.1.7). Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Shipment Lot Testing

S1.1 When Supplementary Requirement S1 is specified on the order, the manufacturer shall make sample tests on the individual lots for shipment to ensure that the product conforms to the specified requirements.

S1.2 The manufacturer shall make an analysis of a randomly selected finished fastener from each lot of product to be shipped. Heat or lot control shall be maintained. The analysis of the starting material from which the fasteners have been manufactured may be reported in place of the product analysis.

S1.3 The manufacturer shall perform mechanical property tests in accordance with this specification and Guide F 1470 on the individual lots for shipment.

S1.4 The manufacturer shall furnish a test report for each lot in the shipment showing the actual results of the chemical analysis and mechanical property tests performed in accordance with Supplementary Requirement S1.

S2. Alloy Control

S2.1 When Supplementary Requirement S2 is specified on the inquiry and order, the manufacturer shall supply that stainless steel specified on the customer’s order with no group substitutions permitted without written permission by the purchaser.

S3. Permeability

S3.1 When Supplementary Requirement S3 is specified on the inquiry and order, the permeability of screws of Condition AF shall not exceed 1.05 at 100 Oe when determined by Test Methods A 342. Screws in Condition CW may not be capable of meeting permeability and hardness requirements simultaneously.

S4. Corrosion Resistance Tests

S4.1 When Supplementary Requirement S4 is specified on
the inquiry and order, corrosion test(s) shall be performed as agreed between the manufacturer and the purchaser at the time of the inquiry or order.

S5. Passivation

S5.1 When Supplementary Requirement S5 is specified on the inquiry and order, the finished product shall be passivated in accordance with Specification A 380.
Standard Specification for Stainless Steel Socket Set Screws [Metric]¹

This standard is issued under the fixed designation F 880M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers the requirements for austenitic grade stainless steel socket set screws (SSS), sizes M1.6 through M24, having Property Classes A1-50 and A1-70.

NOTE 1—This specification is the metric companion of Specification F 880.

1.2 The following hazard caveat pertains only to Section 11, the Test Method Section: This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
A 262 Practices for Detecting Susceptibility to Intergranular Attack in Stainless Steels²
A 342 Test Methods for Permeability of Feebly Magnetic Materials³
A 380 Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems²
A 555/A555M Specification for General Requirements for Stainless Steel Wire and Wire Rods²
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products²
A 967 Specification for Chemical Passivation Treatments for Stainless Steel Parts²
D 3951 Practice for Commercial Packaging⁴
E 3 Practice for Preparation of Metallographic Specimens⁵
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials⁵

E 92 Test Method for Vickers Hardness Metallic Materials⁵
E 384 Test Method for Microindentation Hardness of Materials⁵
F 738M Specification for Stainless Steel Metric Bolts, Screws, and Studs⁶
F 788/F788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series⁶
F 880 Specification for Stainless Steel Socket-Set Screws⁶
F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection⁶

2.2 ASME Standard:
B 18.3.6M Metric Series Socket Set Screws R⁷

3. Classification

3.1 The designation of the property class for the two materials and conditions of this specification shall be consistent with the stainless steel designations in Specification F 738M.

3.2 The austenitic stainless steel socket set screw shall be designation F 880M A1–50 or F 880M A1–70.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Quantity (number of screws);
4.1.2 Dimensions, including nominal thread designation, thread pitch, nominal screw length (millimetres) and point configuration. A standard part number may be used for this definition;
4.1.3 Name of the screw (SSS);
4.1.4 Property Class A1-50 or A1-70;
4.1.5 Coating, if required. If a finish other than passivation is required, it must be specified on the order or product standard;
4.1.6 ASTM designation and year of issue; and
4.1.7 Any special or supplemental requirements.

4.2 Example—50 000 pieces M6 × 1 × 8 cone point SSS A1-70 ASTM F 880M – XX.

¹ This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.04 on Nonferrous Fasteners.


² Annual Book of ASTM Standards, Vol 01.03.
³ Annual Book of ASTM Standards, Vol 03.04.
⁵ Annual Book of ASTM Standards, Vol 03.01.

⁶ Available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112.

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5. Materials and Manufacture

5.1 The screw may be forged, formed, extruded, machined, or ground to meet the dimensional characteristics and performance requirements.

5.2 Heat Treatment—Austenitic alloy Class A1-50 screws shall be annealed by heating to 1040 ± 30°C to obtain maximum corrosion resistance and minimum permeability. The screws shall be held for a sufficient time at temperature, then cooled at a rate sufficient to prevent precipitation of the carbide and provide the properties in accordance with Table 1.

5.3 When Condition A1–70 is specified, the austenitic alloys shall be annealed as specified in 5.2, generally by the raw material manufacturer, then cold worked to develop specific properties.

6. Chemical Composition

6.1 The analysis of the screw material shall conform to the chemical composition specified in Table 2.

6.2 Unless otherwise specified in the inquiry and purchase order (see Supplementary Requirement S2), the choice of alloy used shall be that of the fastener manufacturer, as determined by his fabrication methods and material availability. The specific alloy used by the manufacturer shall be clearly identified on all certification required in the purchase order and shall have a chemical composition conforming to the limits specified in Table 2.

6.3 When chemical analysis is performed by the purchaser using finished fasteners representing each lot, the chemical contents obtained shall conform to the limits specified in Table 2 for the specific alloy. Chemical composition shall conform to the tolerances specified in Specification A 555/A 555M.

6.3.1 In the event of a discrepancy, a referee analysis of the samples for each lot as specified in 12.1, shall be made in accordance with 11.3.1.

7. Mechanical Properties

7.1 Socket set screws, when subjected to a torque test in accordance with 12.2.1, shall withstand application of the test tightening torque specified in Table 2 without evidence of the socket reaming or the screw bursting.

7.2 The hardness of 95 HRB (210 Vickers) maximum for condition A1-50 and 80 HRB (150 Vickers) minimum for condition A1-70 shall be met as determined using Test Methods E 18, E 92, or Test Method E 384 as appropriate.

8. Corrosion Resistance Requirements

8.1 Carbide Precipitation:

8.1.1 Rod, bar, and wire in the austenitic alloys groups 1, 2, 3, except the free-machining grades, 303 and 303Se, used to make fasteners in accordance with this specification shall be capable of passing the test for susceptibility to intergranular corrosion as specified in Practice E of Practices A 262.

8.1.2 As stated in Practices A 262, samples may be subjected to the faster and more severe screening test in accordance with Practice A. Failing Practice A, specimens shall be tested to Practice E and be considered satisfactory if passing Practice E.

9. Dimensions

9.1 Unless otherwise specified, the product shall conform to the requirements of ASME B 18.3.6M.

10. Workmanship, Finish, and Appearance

10.1 Surface Treatment—Unless otherwise specified, screws shall be cleaned, descaled, and passivated in accordance with Practice A 380 or Specification A 967 at the option of the manufacturer.

10.2 Surface Discontinuities:

10.2.1 The surface discontinuities for these products shall conform to Specification F 788/F 788M and the additional limitations specified herein.

10.2.1.1 Processing cracks that connect the socket to the periphery of the screw are not permissible. Defects originating on the periphery with a traverse indicating a potential to intersect are not permissible. For peripheral discontinuities, the maximum depth may be 0.06 D.

11. Number of Tests

11.1 The requirements of this specification shall be met in continuous mass production for stock and the manufacturer

<table>
<thead>
<tr>
<th>TABLE 1 Torsional Strength Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Screw Size</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>1.6</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>2.5</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>16</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>24</td>
</tr>
</tbody>
</table>
shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of fasteners are not ordinarily necessary. A record of the individual heat of steel in each lot shall be maintained. The containers shall be coded to permit identification of the lot.

11.2 When specified in the purchase order, the manufacturer shall furnish a test report of the last complete set of chemical analysis and mechanical tests for each stock size in each shipment.

11.3 When tests of individual shipments are required, Supplementary Requirement S1 must be specified in the inquiry and order.

11.3.1 When the purchaser does not specify the sampling plan and basis of acceptance, the following shall apply:

11.3.1.1 The lot, for purposes of selecting samples, shall consist of all products offered for inspection and testing at one time, that are of the same style, nominal diameter, thread pitch, nominal length, material type, and surface finish.

11.3.1.2 From each lot, samples shall be selected at random and tested for each requirement in accordance with the following:

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and less</td>
<td>1</td>
</tr>
<tr>
<td>Over 800 to 8000, incl</td>
<td>2</td>
</tr>
<tr>
<td>Over 8000 to 22 000, incl</td>
<td>3</td>
</tr>
<tr>
<td>Over 22 000</td>
<td>5</td>
</tr>
</tbody>
</table>

11.3.1.3 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be retested for the requirement(s) in which it failed. All of the additional samples shall conform to the specification or the lot shall be rejected.

11.3.1.4 If the failure of a test specimen is due to improper preparation of the specimen or an incorrect testing technique, the specimen shall be discarded and another test specimen submitted.

11.4 Corrosion Resistance Tests:

11.4.1 Unless otherwise specified, inspection for corrosion resistance shall be in accordance with the manufacturer’s standard quality control practices. No specific method of inspection is required, but the screws shall be produced from suitable raw material and manufactured by properly controlled practices to maintain resistance to corrosion. When corrosion tests are required, Supplementary Requirement S4 must be specified in the inquiry and order, except as noted in 11.4.2.

11.4.2 Products that have been hot worked shall be solution annealed and tested to determine freedom from precipitated carbides. Not less than one corrosion test shall be made from each lot. Corrosion tests shall be performed in accordance with Practices A 262, Practices A or E as applicable.

12. Test Methods

12.1 Chemical Analysis—The chemical composition shall be determined in accordance with Test Method, Practices, and Terminology A 751.

12.1.1 The fastener manufacturer may accept the chemical analysis of each heat of raw material purchased and reported on the raw material certification furnished by the raw material producer. The fastener manufacturer is not required to do any further chemical analysis testing, provided that precise heat lot traceability has been maintained throughout the manufacturing process on each lot of fasteners produced and delivered.

12.2 Mechanical Tests:

12.2.1 For socket strength torque test, the test screw shall be assembled into a tapped hole of 5H tolerance class in a steel block (Fig. 1) until the face of the screw is flush with the top surface of the test block and the set screw bears against a firm
base, such as a hardened screw installed from the opposite side of the block. The applicable hexagon key bit shall be inserted to the full depth of the set screw socket and the test torque listed in Table 1 applied by means of a torque wrench. The screw shall be disassembled from the block and examined for compliance to the requirements of 7.1.

12.3 Corrosion Resistance—When specified on the purchase order or inquiry, corrosion tests to determine freedom from precipitated carbides shall be performed in accordance with Practices A 262, Practice A or E as applicable.

13. Inspection

13.1 If the inspection described in 13.2 is required by the purchaser, it shall be specified in the inquiry, order, or contract.

13.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy that the material is being furnished in accordance with this specification. All tests and inspection required by the specification that are requested by the purchaser’s representative and purchase order shall be made prior to shipment and shall be so conducted as not to interfere unnecessarily with the operation of the work.

14. Rejection and Rehearing

14.1 Screws that fail to conform to the requirements of this specification may be rejected by the purchaser. Rejection shall be reported to the supplier promptly and in writing. In case of dissatisfaction with the results of tests or inspection authorized by the purchaser, the supplier may make claim for a rehearing.

15. Certification

15.1 Test Report—The manufacturer shall maintain on file for a period of 5 years the original test report, including a copy of the certified chemical analysis of the heat of material used and the results of the required testing for the lot of fasteners.

15.2 Manufacturer’s Certificate of Conformance—The manufacturer shall maintain on file for a period of 5 years a certificate indicating that the lot of fasteners was manufactured and tested in accordance with this specification and conforms to all specified requirements.

15.3 When requested by the purchaser, submission of copies of the test report, manufacturer’s certificate or an extension of the 5-year document retention period shall be performed as agreed between the manufacturer and the purchaser at the time of the inquiry or order.

16. Packaging and Package Marking

16.1 Packaging:

16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

16.1.2 When special packaging requirements are required by the purchaser, they shall be defined at the time of inquiry and order.

16.2 Package Marking—Each shipping unit shall include or be plainly marked with the following:

16.2.1 ASTM specification,
16.2.2 Property class,
16.2.3 Alloy number,
16.2.4 Size,
16.2.5 Name and brand or trademark of the manufacturer,
16.2.6 Country of origin,
16.2.7 Number of pieces, and
16.2.8 Purchase order number.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry and order (see 4.1.7). Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Shipment Lot Testing

S1.1 When Supplementary Requirement S1 is specified on the order, the manufacturer shall make sample tests on the individual lots for shipment to ensure that the product conforms to the specified requirements.

S1.2 The manufacturer shall make an analysis of a randomly selected finished fastener from each lot of product to be shipped. Heat or lot control shall be maintained. The analysis of the starting material from which the fasteners have been manufactured may be reported in place of the product analysis.

S1.3 The manufacturer shall perform mechanical property tests in accordance with this specification and Guide F 1470 on the individual lots for shipment.

S1.4 The manufacturer shall furnish a test report for each lot in the shipment showing the actual results of the chemical analysis and mechanical property tests performed in accordance with Supplementary Requirement S1.

S2. Alloy Control

S2.1 When Supplementary Requirement S2 is specified on the inquiry and order, the manufacturer shall supply that stainless steel specified on the customer’s order with no group substitutions permitted without written permission by the purchaser.

S3. Permeability

S3.1 When Supplementary Requirement S3 is specified on the inquiry and order, the permeability of screws of Class A1 shall not exceed 1.05 at 100 Oe when determined by Test Methods A 342. Screws in property Class A1-70 may not be capable of meeting permeability and hardness requirements simultaneously.
S4. Corrosion Resistance Tests

S4.1 When Supplementary Requirement S4 is specified on the inquiry and order, corrosion test(s) shall be performed as agreed between the manufacturer and the purchaser at the time of the inquiry or order.

S5. Passivation

S5.1 When Supplementary Requirement S5 is specified on the inquiry and order, the finished product shall be passivated in accordance with Specification A 380.
Standard Specification for
Aluminum Transmission Tower Bolts and Nuts

1. Scope
   1.1 This specification covers aluminum structural bolts and nuts for use in the construction of aluminum transmission towers, substations, and similar aluminum structures.
   1.2 Diameters of bolts and nuts furnished to this specification are 5/8, 3/4, and 7/8 in.
   1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents
   2.1 ASTM Standards:
   - B 565 Test Method for Shear Testing of Aluminum and Aluminum-Alloy Rivets and Cold-Heading Wire and Rods
   - D 3951 Practice for Commercial Packaging
   - E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
   - E 34 Test Methods for Chemical Analysis of Aluminum and Aluminum-Base Alloys
   - E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition
   - E 101 Test Method for Spectrographic Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique
   - E 227 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique
   - F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
   - F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

   2.2 ASME Standards:
   - B1.1 Unified Inch Screw Threads (UN and UNR Thread Form)
   - B18.2.1 Square and Hex Bolts and Screws (Inch Series) Addenda A
   - B18.2.2 Square and Hex Nuts

   2.3 Military Standard:
   - MIL-STD-A-8625 Anodic Coatings for Aluminum and Aluminum Alloys

3. Ordering Information
   3.1 Orders for bolts and nuts under this specification shall include the following:
   - 3.1.1 Quantity (number of pieces of each item and size);
   - 3.1.2 Name of item;
   - 3.1.3 Size (diameter, threads per inch, length);
   - 3.1.4 Alloy number;
   - 3.1.5 Shipment lot testing, as required (see Supplementary Requirements S1);
   - 3.1.6 Source inspection, if required (see Section 14);
   - 3.1.7 Certificate of compliance or test report, if required (see Section 16);
   - 3.1.8 Additional requirements, if any, to be specified on the purchase order (see 4.2.1, 4.2.3, 8.2.1, 8.2.2, 9.2, 12.1, and 13.1);
   - 3.1.9 Supplementary requirements, if any; and
   - 3.1.10 ASTM specification and year of issue.

   Note 1—Example: 10,000 pieces Aluminum Transmission Tower Bolt, 0.750-10 by 2.00 in., Alloy 2024-T4, Furnish Certificate of Compliance, Supplementary Requirement S2, ASTM F 901–XX.

4. Materials and Manufacture
   4.1 Materials—Bolts shall be manufactured from Alloy 2024 and nuts from Alloy 6061 or 6262. The materials chemical composition shall be capable of developing the mechanical properties required by Table 1, when in the finished condition.

   4.2 Manufacture:
   - 4.2.1 Forming—Unless otherwise specified, the bolts and nuts shall be cold formed, hot formed, or machined from
TABLE 1  Tensile Strength of 2024-T4 Bolts and Proof Loads for 6061-T6 and 6262-T9 Nuts\(^4\)

<table>
<thead>
<tr>
<th>Bolt Size, in.</th>
<th>Tensile Strength, min, lb (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>%4</td>
<td>12 400 (55)</td>
</tr>
<tr>
<td>%3</td>
<td>18 400 (82)</td>
</tr>
<tr>
<td>%6</td>
<td>25 400 (113)</td>
</tr>
</tbody>
</table>

\(^4\) Based on a tensile unit stress of 55 000 psi (380 MPa) and the thread stress area calculated as follows:

\[
A_s = 0.7854 \left(\frac{D}{n}\right)^2 - 0.9743(n/2)\]

where:

- \(A_s\) = stress area,
- \(D\) = nominal diameter, and
- \(n\) = threads/in.

TABLE 2 Chemical Requirements\(^A,B\)

<table>
<thead>
<tr>
<th>UNS Designation Number</th>
<th>Alloy</th>
<th>General Name</th>
<th>Aluminum(^C)</th>
<th>Chromium</th>
<th>Copper</th>
<th>Iron</th>
<th>Manganese</th>
<th>Silicon</th>
<th>Titanium</th>
<th>Zinc</th>
<th>Magnesium</th>
<th>Other Elements Each</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A92024</td>
<td>2024</td>
<td>Aluminum 2024</td>
<td>Balance</td>
<td>0.10</td>
<td>3.8–4.9</td>
<td>0.50</td>
<td>0.30–0.9</td>
<td>0.50</td>
<td>0.15</td>
<td>0.25</td>
<td>1.2–1.8</td>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td>A96061</td>
<td>6061</td>
<td>Aluminum 6061</td>
<td>Balance</td>
<td>0.04–0.35</td>
<td>0.15–0.40</td>
<td>0.7</td>
<td>0.15</td>
<td>0.40–0.8</td>
<td>0.15</td>
<td>0.25</td>
<td>0.8–1.2</td>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td>A96262</td>
<td>6262</td>
<td>Aluminum 6262</td>
<td>Balance</td>
<td>0.04–0.14</td>
<td>0.15–0.40</td>
<td>0.7</td>
<td>0.15</td>
<td>0.40–0.8</td>
<td>0.15</td>
<td>0.25</td>
<td>0.8–1.2</td>
<td>0.05(^D)</td>
<td>0.15</td>
</tr>
</tbody>
</table>

\(^A\) Limits are in percent, maximum, unless shown as a range or stated otherwise.

\(^B\) Analysis shall be made only for the elements specified in this table. If, however, the presence of other elements is suspected or indicated in amounts greater than the specified limits, further analysis shall be made to determine that these elements are not present in excess of the specified limits.

\(^C\) Balance shall be arithmetically computed by deducting the sum of the other named elements from 100.

\(^D\) Lead 0.4–0.7%; bismuth 0.4–0.7%.

TABLE 3 Sample Size and Acceptance for Mechanical Property Tests

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Tests</th>
<th>Acceptance Number</th>
<th>Rejection Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 and under</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>51 to 500</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>501 to 35 000</td>
<td>5</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>35 001 to 100 000</td>
<td>8</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

suitable material at the option of the manufacturer.

4.2.2 Condition—The fasteners shall be furnished in the following conditions:

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Fastener</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>2024-T4</td>
<td>bolts</td>
<td>solution treated and naturally aged</td>
</tr>
<tr>
<td>6061-T6</td>
<td>nuts</td>
<td>solution treated and artificially aged</td>
</tr>
<tr>
<td>6262-T9</td>
<td>nuts</td>
<td>solution treated, artificially aged, and cold worked</td>
</tr>
</tbody>
</table>

4.2.3 Threads—Unless otherwise specified, the threads shall be rolled or cut at the option of the manufacturer.

5. Chemical Composition

5.1 Chemical Composition Limits—The bolts and nuts shall conform to the requirements as to chemical composition prescribed in Table 2.

5.2 Manufacturer’s Analysis—When test reports are required on the inquiry or purchase order (see 3.1.7), the manufacturer shall furnish a certificate of conformance certifying compliance with the chemical limits specified in Table 2.

5.3 Product Analysis:

5.3.1 Product analysis shall be made by the purchaser from finished products representing each lot. The chemical composition thus determined shall conform to the requirements in Table 2.

5.3.2 In the event of disagreement, a referee chemical analysis shall be performed if agreed upon by both parties. A sample as required by Table 3 shall be selected for each lot. Chemical analysis shall be performed to the requirements of 13.1 and the result shall conform to Table 2.

6. Mechanical Properties

6.1 Bolts—Bolts having a length three times the diameter or longer shall be tested full size as specified in 13.2.2. At the manufacturer’s option, bolts of less than 3 diameters in length may be tested in full size as specified in 13.2.2. Bolts subjected to tension tests shall meet the tensile strength requirements specified in Table 1. Bolts of less than 3 diameters in length or for other reasons cannot be tested full size in tension, shall be subject to a shear test to be performed in accordance with 12.2.1. The test results shall conform to the following minimum shear-strength requirements: 37 ksi (255 MPa) for 2024-T4.

6.2 Nuts—Nuts shall be tested in accordance with the mechanical requirements for the applicable type and shall meet the minimum proof-load requirements in Table 1.

7. Significance of Numerical Limits

7.1 For purposes of determining compliance with the specified limits for requirements of the properties listed in this specification, an observed value or calculated value shall be rounded in accordance with Practice E 29.

8. Dimensions

8.1 Bolts and Nuts:

8.1.1 Bolts—Bolts shall be full-size body in accordance with the requirements of AMSE B18.2.1, except the full-body length listed in Table 4 shall be the basis of manufacture and inspection. Unless otherwise specified, hex bolts shall be furnished. The ends of the bolts need not be chamfered or pointed.

8.1.2 Nuts—The dimensions of the nuts shall be in accordance with the requirements of AMSE B 18.2.2. Unless otherwise specified, nuts are to be either the regular hex series or a recessed hex series that allows penetration of the bolt threads into the nut recess area.

8.2 Threads:

8.2.1 Bolts—Unless otherwise specified, the bolts shall be Class 2A threads in accordance with AMSE B1.1.

8.2.2 Nuts—Unless otherwise specified, the nuts shall be Class 2B threads in accordance with AMSE B1.1.
9. Workmanship, Finish, and Appearance

9.1 Workmanship—Bolts and nuts shall have a workmanlike finish free of injurious burrs, seams, laps, irregular surfaces, and other imperfections affecting serviceability.

9.2 Finish:

9.2.1 Bolts—Unless otherwise specified, bolts shall be furnished anodized per MIL-STD-A-8625, Type II, Class 2 and color coded for length as indicated in Table 4.

9.2.2 Nuts—Unless otherwise specified, nuts shall be furnished waxed.

10. Sampling

10.1 A lot, for the purposes of selecting test specimens, shall consist of no more than 100,000 pieces offered for inspection at one time having the following common characteristics:

10.1.1 One type of item (that is, bolts or nuts),
10.1.2 Same alloy and temper,
10.1.3 One nominal diameter and thread series, and
10.1.4 One nominal length or thickness.

11. Number of Tests and Retests

11.1 Tests—The requirements of this specification shall be met in continuous mass production for stock. The manufacturer shall make sample inspections, as specified in Table 3, to ensure that the product conforms to the specified requirements. When tests of individual shipments are required, Supplementary Requirement S1 must be specified.

11.2 Retests:

11.2.1 When tested in accordance with the required sampling plan, a lot shall be subject to rejection if any of the test specimens fails to meet the applicable test requirement.

11.2.2 If the failure of a test specimen is due to improper preparation of the specimen or to incorrect testing technique, the specimen shall be discarded and another specimen substituted.

12. Specimen Preparation

12.1 Chemical Tests—When required, samples for chemical analysis shall be taken in accordance with Practice E 55 by drilling, sawing, milling, turning, clipping, or other such methods capable of producing representative samples.

12.2 Mechanical Tests:

12.2.1 Bolts—Machined shear test specimens, when required, shall be taken in accordance with Test Method B 565.

12.2.2 Nuts—Nuts shall be tested in full section.

13. Test Methods

13.1 Chemical Analysis—The chemical composition may be determined by any recognized commercial test method. In the event of disagreement, the following test methods shall be used for referee purposes: E 34, E 101, or E 227.

13.2 Mechanical:

13.2.1 Tests shall be conducted in accordance with Test Methods B 565 and F 606.

13.2.2 Bolts that can be tested full size shall be tested using the wedge tension test specified in Test Methods F 606. Fracture shall be in the body or threaded portion of the bolt without any failure at the junction of the head and body.

13.2.3 When machined specimens for shear tests are necessary (see Section 6), determine the shear strength on each sample in accordance with Test Method B 565.

13.2.4 Nuts shall be proof-load or proof-stress tested as specified in Test Methods F 606.

14. Inspection

14.1 When specified on the inquiry or purchase order, the product shall be subject to inspection by the purchaser at the place of manufacture prior to shipment. The inspector representing the purchaser shall have controlled entry only to those parts of the manufacturer’s operations that concern the manufacturer of the ordered product and only when and where work on the contract of the purchaser is being performed. The manufacturer shall afford the inspector all reasonable facilities to satisfy that the product is being furnished in accordance with this specification. All inspections and tests shall be conducted so as not to interfere unnecessarily with the operations of the manufacturer.

15. Rejection and Rehearing

15.1 Unless otherwise specified, any rejection based on tests specified herein and made by the purchaser shall be reported to the manufacturer as soon as is practical after receipt of the product by the purchaser.

16. Certification and Test Reports

16.1 Certificate of Compliance—When specified in the contract or purchase order, the manufacturer shall furnish certification that the product was manufactured and tested in accordance with this specification and conforms to all specified requirements.

16.2 Test Reports—When shipment lot testing in accordance with Supplementary Requirement S1 is specified in the contract or purchase order, the manufacturer shall furnish a test report showing the results of the mechanical tests for each lot shipped.

---

### TABLE 4 Length of Full Body for Bolts

<table>
<thead>
<tr>
<th>Length of Bolt, in.</th>
<th>Color Code</th>
<th>Bolt Diameter, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>( \frac{1}{8} )</td>
</tr>
<tr>
<td>1</td>
<td>Red</td>
<td>...</td>
</tr>
<tr>
<td>1( \frac{1}{4} )</td>
<td>Blue</td>
<td>( \frac{1}{8} )</td>
</tr>
<tr>
<td>1( \frac{1}{2} )</td>
<td>Gold</td>
<td>( \frac{1}{8} )</td>
</tr>
<tr>
<td>1( \frac{3}{4} )</td>
<td>Green</td>
<td>( \frac{5}{32} )</td>
</tr>
<tr>
<td>2</td>
<td>Red</td>
<td>( \frac{3}{16} )</td>
</tr>
<tr>
<td>2( \frac{1}{4} )</td>
<td>Blue</td>
<td>( \frac{1}{8} )</td>
</tr>
<tr>
<td>2( \frac{1}{2} )</td>
<td>Gold</td>
<td>( \frac{5}{32} )</td>
</tr>
<tr>
<td>2( \frac{3}{4} )</td>
<td>Green</td>
<td>( \frac{5}{32} )</td>
</tr>
<tr>
<td>3</td>
<td>Red</td>
<td>( \frac{3}{16} )</td>
</tr>
<tr>
<td>3( \frac{1}{4} )</td>
<td>Blue</td>
<td>2</td>
</tr>
<tr>
<td>3( \frac{1}{2} )</td>
<td>Gold</td>
<td>( \frac{5}{32} )</td>
</tr>
<tr>
<td>3( \frac{3}{4} )</td>
<td>Green</td>
<td>( \frac{5}{32} )</td>
</tr>
<tr>
<td>4</td>
<td>Red</td>
<td>2( \frac{3}{16} )</td>
</tr>
</tbody>
</table>

---

\(^a\) The length of full body is the distance from the underside of the head to the first scratch of thread on bolts with machine-cut threads, or top of the extrusion angle for bolts with rolled threads with a tolerance of \( \pm \frac{1}{32} \) in. for \( \frac{1}{8} \)- and \( \frac{1}{4} \)-in. size bolts, and \( \pm \frac{1}{64} \) in. for \( \frac{3}{16} \)-in. size bolts.
17. Product Marking, Packaging, and Shipping

17.1 Bolt heads shall be marked to identify the manufacturer. The manufacturer may use additional markings for his own use. Markings shall be raised or depressed, at the option of the manufacturer. Nuts are not required to be marked.

17.2 Bolts and nuts shall be shipped assembled unless otherwise specified.

17.3 Packaging:

17.3.1 Unless otherwise specified packaging shall be in accordance with Practice D 3951.

17.3.2 When special packaging requirements are required by the purchaser, they shall be defined at the time of inquiry and order.

17.4 Package Marking:

Each shipping unit shall include or be plainly marked with the following:

17.4.1 ASTM specification,
17.4.2 Alloy condition,
17.4.3 Alloy number,
17.4.4 Size,
17.4.5 Name and brand or trademark of the manufacturer,
17.4.6 Country of origin,
17.4.7 Number of pieces, and
17.4.8 Purchase order number.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contact, or order. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Shipment Lot Testing

S1.1 When Supplementary Requirement S1 is specified on the order, the manufacturer shall make sample tests on the individual lots for shipment to ensure that the product conforms to the specified requirements.

S1.2 The manufacturer shall make an analysis of a randomly selected finished fastener from each lot of product to be shipped. If heat or lot control has been maintained, the analysis of the starting material from which the fasteners have been manufactured may be reported in place of the product analysis.

S1.3 The manufacturer shall perform mechanical property tests in accordance with this specification and Guide F 1470 on the individual lots for shipment.

S1.4 The manufacturer shall furnish a test report for each lot in the shipment showing the actual results of the chemical analysis and mechanical property tests performed in accordance with Supplementary Requirement S1.

S2. Product Marking

S2.1 Bolts shall be marked with their nominal length in inches and fractions.
Standard Specification for 
Alloy Steel Socket Set Screws

This standard is issued under the fixed designation F 912; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This specification covers the requirements for quenched and tempered alloy steel socket-set screws (SSS) 0.060 through 2.000-in. sizes having hardnesses 45 to 53 HRC.

1.2 These set screws are intended for compression applications only and are not customarily subjected to embrittlement tests. For tensile applications, consult with the manufacturer for proper alloy and hardness.

1.3 The hazard statement pertains only to the test method section, Section 11 of this specification. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

NOTE 1—A complete metric companion to Specification F 912 has been developed—F 912M; therefore, no metric equivalents are shown in this Specification.

2. Referenced Documents

2.1 ASTM Standards:
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
D 3951 Practice for Commercial Packaging
E 3 Methods of Preparation of Metallographic Specimens
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
E 112 Test Methods for Determining Average Grain Size
E 384 Test Method for Microhardness of Materials
F 788/F788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series

2.2 ANSI/ASME Standards:
B18.3 Socket Cap, Shoulder and Set Screw, Inch Series

4. Materials and Manufacture

4.1 The screws shall be fabricated from alloy steel made to fine grain practice. In the event of controversy over grain size, referee tests on finished screws conducted in accordance with Test Methods E 112 shall prevail.

4.2 The screws may be forged, formed, extruded, machined, or ground to meet the dimensional characteristics and performance requirements.

4.3 Set screws shall be heat treated by quenching in oil from above the transformation temperature and then tempered to meet the hardness range specified in 6.2.

4.4 Standard Finishes—Unless otherwise specified, the screws shall be furnished with one of the following standard surfaces as manufactured, at the option of the manufacturer: (1) bright uncoated; (2) thermal black oxide; or (3) chemical black oxide. Hydrogen embrittlement tests shall not be required for screws furnished in these conditions.

4.5 Protective Coatings:
4.5.1 When a protective finish other than as specified in 4.4 is required, it shall be specified on the purchase order with the applicable finish specification.

4.5.2 When protective or decorative coatings are applied to

Note 1—A Summary of Changes section appears at the end of this standard.

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the screws, precautions specified by the coating requirements to minimize embrittlement shall be exercised.

5. Chemical Composition

5.1 The chemical composition of the screw material shall conform to the heat analysis specified in Table 1.

5.2 One or more of the following alloying elements: chromium, nickel, molybdenum, or vanadium shall be present in the steel in sufficient quantity to assure the specific strength properties are met after oil quenching and tempering. The steel shall meet the AISI definition of alloy steel, that is, maximum and minimum element content requirement or minimum element limits specified.

5.3 Alloy steel to which bismuth, selenium, tellurium, or lead has been intentionally added to improve machinability shall be permitted.

5.4 Material analysis may be made by the purchaser from finished products and the chemical composition thus determined shall conform to the requirements specified for the product analysis in Table 1.

6. Mechanical Properties

6.1 Socket set screws when subjected to a torque test in accordance with 11.2 shall withstand application of the test tightening torque specified in Table 2 without evidence of the socket reaming or the screw bursting.

6.2 Socket set screws shall have a hardness of 45 to 53 HRC. The hardness limits shall apply throughout the screw from core to surface.

7. Other Requirements

7.1 Decarburization:

7.1.1 There shall be no evidence of gross decarburization of the surfaces of the heat-treated screws when measured in accordance with 11.4.

7.1.2 The depth of partial decarburization shall be limited to the values in Table 3 when measured as shown in Fig. 1, and in accordance with 11.4.

8. Dimensions

8.1 Unless otherwise specified, the product shall conform to the requirements of ANSI/ASME B 18.3.

9. Workmanship, Finish, and Appearance

9.1 Surface Discontinuities:

9.1.1 The surface discontinuities for these products shall conform to Specification F 788/F 788M and the additional limitations specified herein.

<table>
<thead>
<tr>
<th>TABLE 1 Chemical Requirements</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Element</th>
<th>Heat Analysis</th>
<th>Product Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>0.30 to 0.48</td>
<td>0.28 to 0.50</td>
</tr>
<tr>
<td>Phosphorus, max</td>
<td>0.035</td>
<td>0.040</td>
</tr>
<tr>
<td>Sulfur, max</td>
<td>0.040</td>
<td>0.045</td>
</tr>
</tbody>
</table>

9.1.2 Processing defects that connect the socket to the periphery of the screw are not permissible. Defects originating on the periphery and with a traverse indicating a potential to intersect are not permissible.

9.1.3 Quench cracks of any depth, any length, or in any location are not permitted.

10. Number of Tests

10.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make ample inspections to insure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated. A record of individual heats of steel in each test lot shall be maintained. The container shall be coded to permit identification of the lot.

10.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last complete set of mechanical tests for each stock size in each shipment.

10.3 When additional tests are specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all screws offered for inspection at one time of one diameter and length. From each lot, the number of samples for each requirement shall be as follows: (Note: This will be aligned with F 16.02 assurance decision.)

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and less</td>
<td>1</td>
</tr>
<tr>
<td>Over 800 to 8000, incl</td>
<td>2</td>
</tr>
<tr>
<td>Over 8000 to 22 000, incl</td>
<td>3</td>
</tr>
<tr>
<td>Over 22 000</td>
<td>5</td>
</tr>
</tbody>
</table>

10.4 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be retested for the requirement(s) in which it failed. All of the additional samples shall conform to the specification or the lot shall be rejected.

11. Test Methods

11.1 Chemical analysis shall be conducted in accordance with Test Methods A 751.

11.2 For socket strength torque test, the test screw shall be assembled into a tapped hole of 2B tolerance class in a steel block (see Fig. 2) until the face of the screw is flush with the top surface of the test block and the set screw bears against a firm base, such as a hardened screw installed from the opposite side of the block. The applicable hexagon key bit in accordance with ANSI/ASME B 18.3 shall be inserted to the full depth of the set screw socket and the test torque listed in Table 2 applied by means of a torque wrench. The screw shall be disassembled from the block and examined for compliance to the requirements of 6.1.

11.3 Hardness shall be determined in accordance with Test Methods E 18.

11.4 Decarburization and carburization tests shall be conducted as follows:

11.4.1 Section the thread area of the screw longitudinally through the axis, mount, and polish it in accordance with Methods E 3. Use one of the two methods for carburization or decarburization evaluation: either optical or microhardness.
measurements. The microhardness measurement shall constitute a referee method in case of dispute.

11.4.2 For optical measurement, etch the section in 2–4% nitral. Examine the surface of the etched samples under a microscope at 100x using a measuring eyepiece graduated in 0.001-in. increments. The width of any light etching band normally defines the decarburization depth. A dark etching band indicates the possibility of carburization.

11.4.3 Measure microhardness in accordance with Test Method E 384 on unetched specimens using a DPH 136° indenter or a Knoop indenter using the following load application:

<table>
<thead>
<tr>
<th>Number of Threads per inch</th>
<th>Load per inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 40</td>
<td>500 gf</td>
</tr>
<tr>
<td>40, 44, and 48</td>
<td>200 gf</td>
</tr>
<tr>
<td>4.5 and 5</td>
<td>Use optical evaluation in 11.4.4</td>
</tr>
</tbody>
</table>

11.4.3.1 Screw threads greater than 48 threads per inch, optical evaluation as described in 11.4.2 shall determine conformance to specification requirements. Take measurements at the minor diameter (Reading No. 1) on the thread crest bisector to determine base material hardness. Take measurements (Reading No. 2) on the bisector 0.75 h, from the minor measurement toward the thread crest. Also take measurements (Reading No. 3) on the thread flank at the pitch line at a depth within 0.003 in. from the surface. Reading No. 3 may be taken on the same or an adjacent thread.

11.4.4 Interpret Microhardness Readings as Follows:

11.4.4.1 A decrease of more than 30 hardness points from Reading No. 1 to Reading No. 2 shall be regarded as decarburization and indicates the screw does not conform to specification requirements.

11.4.4.2 An increase of more than 30 hardness points from Reading No. 1 to Reading No. 3 shall be regarded as carburization and indicates that the screw does not conform to specification requirements.

12. Inspection

12.1 The inspector representing the purchaser, upon reasonable notice, shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material
ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser’s representative shall be made before shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

14. Certification

14.1 Upon request of the purchaser in the contract or order, a manufacturer’s certification that the material was manufactured and tested in accordance with this specification, together with a report of the latest mechanical tests of each stock size in each shipment, shall be furnished at the time of shipment.

15. Responsibility

15.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

16. Packaging and Package Marking

16.1 Packaging:

16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

16.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

16.2 Package Marking:

16.2.1 Each shipping unit shall include or be plainly marked with the following information:

16.2.1.1 ASTM designation,
16.2.1.2 Size,
16.2.1.3 Name and brand or trademark of the manufacturer,
16.2.1.4 Number of pieces,
16.2.1.5 Purchase order number, and
16.2.1.6 Country of origin.

17. Keywords

17.1 alloy; set; socket; steel
SUMMARY OF CHANGES

This section identifies the location of selected changes to this standard that have been incorporated since the –99 issue. For the convenience of the user, Committee F16 has highlighted those changes that impact the use of this standard. This section may also include descriptions of the changes or reasons for the changes, or both.


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Standard Specification for
Alloy Steel Socket Set Screws [Metric]1

This standard is issued under the fixed designation F 912M; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This specification covers the requirements for quenched and tempered alloy steel socket set screws (SSS) M1.6 through
M24 sizes having hardnesses 45 to 53 HRC, ISO 898/5 property class 45H.

1.2 These set screws are intended for compression applications only and are not customarily subjected to embrittlement
tests. For tensile applications, consult with the manufacturer
for proper alloy and hardness.

1.3 The hazard statement pertains only to the test method
section, Section 11 of this specification. This standard does not
purport to address all of the safety concerns, if any, associated
with its use. It is the responsibility of the user of this standard
to establish appropriate safety and health practices and
determine the applicability of regulatory limitations prior to
use.

Note 1—This specification is the metric companion of Specification
F 912.

2. Referenced Documents

2.1 ASTM Standards:
A 751 Test Methods, Practices, and Terminology for
Chemical Analysis of Steel Products2
D 3951 Practice for Commercial Packaging3
E 3 Methods of Preparation of Metallographic Specimens4
E 18 Test Methods for Rockwell Hardness and Rockwell
Superficial Hardness of Metallic Materials4
E 112 Test Methods for Determining Average Grain Size4
E 384 Test Method for Microhardness of Materials4
F 788/F788M Specification for Surface Discontinuities of
Bolts, Screws, and Studs, Inch and Metric Series5

2.2 ANSI/ASME Standards:
B18.3.6M Hexagon Socket Set Screws Metric Series6
B18.24.1 Part Identifying Number (PIN) Code System7

2.3 ISO Standard:
898/5 Mechanical Properties of Fasteners—Set Screws and
Similar Threaded Fasteners Not Under Tensile Stress6

3. Ordering Information

3.1 Orders for material under this specification shall include
the following information:
3.1.1 Quantity (number of screws).
3.1.2 Dimensions, including nominal thread designation,
thread pitch, nominal screw length (millimetres) and point
configuration. A standard part number may be used for this
definition.
3.1.3 Name of the screw (SSS).
3.1.4 Coating, if required. See 4.4.
3.1.5 Lot testing, if required. See 10.3.
3.1.6 Certification, if required. See 14.1.
3.1.7 ASTM designation and year of issue.
3.1.8 Any special or supplemental requirements.
3.1.9 For establishment of a part identifying system, see
ASME B18.24.1.

Example—50 000 pieces M6x1x8 cone point SSS—
certification per 14.1—ASTM F 912M–__ (state issue date), or
25000 pcs B1836A 060008K SSS—certification per 14.1—
ASTM F 912M–__ (state issue date).

4. Material and Manufacture

4.1 The screws shall be fabricated from alloy steel made to
a fine grain practice. In the event of controversy over grain
size, referee tests on finished screws conducted in accordance
with Test Method E 112 shall prevail.
4.2 The screw may be forged, formed, extruded, machined,
or ground to meet the dimensional characteristics and performance
requirements.
4.3 Set screws shall be heat treated by quenching in oil from
above the transformation temperature and then tempered by
reheating to meet the hardness range specified in 6.2.

---

1 Available from American National Standards Institute, 11 West 42nd Street,
13th Floor, New York, NY 10036.
7 Available from American Society of Mechanical Engineers, Three Park
Avenue, New York, NY 10016–5990.

*A Summary of Changes section appears at the end of this standard.

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4.4 Standard Finishes—Unless otherwise specified, the screws shall be furnished with one of the following standard surfaces as manufactured, at the option of the manufacturer; (1) bright uncoated; (2) thermal black oxide; or (3) chemical black oxide. Hydrogen embrittlement tests shall not be required for screws furnished in these conditions.

4.5 Protective Coatings:

4.5.1 When a protective finish other than as specified in 4.4 is required, it shall be specified on the purchase order with the applicable finish specification.

4.5.2 When protective or decorative coatings are applied to the screws, precautions specified by the coating requirements to minimize embrittlement shall be exercised.

5. Chemical Composition

5.1 The chemical composition of the screw material shall conform to the heat analysis specified in Table 1.

5.2 One or more of the alloying elements chromium, nickel, molybdenum, or vanadium shall be present in the steel in sufficient quantity to assure that specific strength properties are met after oil quenching and tempering. The steel shall meet the AISI definition of alloy steel, that is, maximum and minimum element content requirement or minimum element limits specified.

5.3 Alloy steel to which bismuth, selenium, tellurium, or lead has been intentionally added to improve machinability shall be permitted.

5.4 Material analysis may be made by the purchaser from finished products and the chemical composition thus determined shall confirm to the requirements specified for the product analysis in Table 1.

6. Mechanical Properties

6.1 Socket set screws when subjected to a torque test in accordance with 11.2 shall withstand application of the test tightening torque specified in Table 2 without evidence of the socket reaming or the screw bursting.

6.2 Socket set screws shall have a hardness of 45 to 53 HRC. The point end hardness within 0.04 mm distance from the surface shall be equal to or greater than the measured core hardness but shall not exceed 53 HRC (560 DPH).

7. Other Requirements

7.1 Decarburization:

7.1.1 There shall be no evidence of gross decarburization of the surfaces of the heat-treated screws when measured in accordance with 11.4.

7.1.2 The depth of partial decarburization shall be limited to the values in Table 3 when measured as shown in Fig. 1 and 2.

<table>
<thead>
<tr>
<th>Table 1 Chemical Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Carbon</td>
</tr>
<tr>
<td>Phosphorus, max</td>
</tr>
<tr>
<td>Sulfur, max</td>
</tr>
</tbody>
</table>

Note: 1—Plus alloys per 5.2.

<table>
<thead>
<tr>
<th>Table 2 Torsional Strength Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Screw Size</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>1.6</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>2.5</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>16</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>24</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3 Decarburization Limits for Threads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thread Pitch, ( P ), mm</td>
</tr>
<tr>
<td>0.7</td>
</tr>
<tr>
<td>0.8</td>
</tr>
<tr>
<td>1.0</td>
</tr>
<tr>
<td>1.25</td>
</tr>
<tr>
<td>1.5</td>
</tr>
<tr>
<td>1.75</td>
</tr>
<tr>
<td>1.0</td>
</tr>
<tr>
<td>1.25</td>
</tr>
<tr>
<td>1.5</td>
</tr>
<tr>
<td>1.75</td>
</tr>
<tr>
<td>1.75</td>
</tr>
<tr>
<td>2.0</td>
</tr>
<tr>
<td>2.5</td>
</tr>
</tbody>
</table>

\( ^a \) See Fig. 2.

in accordance with 11.4.

8. Dimensions

8.1 Unless otherwise specified, the product shall conform to the requirements of ANSI/ASME B18.3.6M.

9. Workmanship, Finish, and Appearance

9.1 Surface Discontinuities:

9.1.1 The surface discontinuities for these products shall conform to Specification F 788/F 788M and the additional limitations specified herein.

9.1.2 Processing defects that connect the socket to the periphery of the screw are not permissible. Defects originating on the periphery and with a traverse indicating a potential to intersect are not permissible.

9.1.3 Threads shall have no laps at the root or on the flanks, as shown in Fig. 2(a). Laps are permitted at the crest (Fig. 2(c)) that do not exceed 25 % of the basic thread depth and on the flanks outside the pitch cylinder. Longitudinal seams rolled beneath the root of the thread and across the crests of cut threads are acceptable within the limits of 0.03 D or 0.2 mm, whichever is greater.
9.1.4 Quench cracks of any depth, any length, or in any location are not permitted.

10. Number of Tests

10.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated. A record of individual heats of steel in each test lot shall be maintained. The container shall be coded to permit identification of the lot.

10.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last complete set of mechanical tests for each stock size in each shipment.

10.3 When additional tests are specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all screws offered for inspection at one time of one diameter and length. From each lot, the number of samples for each requirement shall be as follows:

<table>
<thead>
<tr>
<th>Number of Pieces in Lot</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 and less</td>
<td>1</td>
</tr>
<tr>
<td>Over 800 to 8000, incl</td>
<td>2</td>
</tr>
<tr>
<td>Over 8000 to 22 000, incl</td>
<td>3</td>
</tr>
<tr>
<td>Over 22 000</td>
<td>5</td>
</tr>
</tbody>
</table>

10.4 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be retested for the requirement(s) in which it failed. All of the additional samples shall conform to the specification or the lot shall be rejected.

11. Test Methods

11.1 Chemical analysis shall be conducted in accordance with Test Methods A 751.

11.2 For socket strength torque test, the test screw shall be assembled into a tapped hole of 5H tolerance class in a steel block (see Fig. 3) until the face of the screw is flush with the top surface of the test block and the set screw bears against a firm base, such as a hardened screw installed from the opposite side of the block. The applicable hexagon key bit shall be
inserted to the full depth of the set screw socket and the test torque listed in Table 2 applied by means of a torque wrench. The screw shall be disassembled from the block and examined for compliance to the requirements of 6.1.

11.3 Hardness shall be determined in accordance with Test Methods E 18.

11.4 Decarburization Tests Shall Be Conducted as Follows:

11.4.1 Section the thread area of the screw longitudinally through the axis, mount, and polish it in accordance with Methods E 3. Take measurements (1) at the minor diameter in the center of the thread ridge, (2) 0.75 h toward the thread crest on the perpendicular bisector of the thread ridge, (3) on the thread flank approximately at the pitch line at a depth of 0.08 mm, and (4) in the thread root at a depth of 0.1 h. Use one of the two methods for decarburization evaluation, either optical or microhardness measurements. The microhardness measurement shall constitute a referee method in case of dispute.

11.4.2 For optical measurement, etch the section in 2–4 % nital. Examine the surface of the etched samples under a microscope at 100× using a measuring eyepiece graduated in 0.03-mm increments. The width of any light etching band normally defines the decarburization depth. A dark etching band indicates the possibility of carburization.

11.4.3 Measure microhardness in accordance with Test Method E 384 on unetched specimens using a DPH 136° indenter or a Knoop indenter using the following load application:

<table>
<thead>
<tr>
<th>Thread Pitch, P, min.</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 0.6</td>
<td>500 gf</td>
</tr>
<tr>
<td>0.6</td>
<td>200 gf</td>
</tr>
<tr>
<td>Less than 0.6</td>
<td>Use optical evaluation in 11.4.2</td>
</tr>
</tbody>
</table>

11.4.3.1 Screw threads greater than 48 threads per inch, optical evaluation as described in paragraph 11.4.2 shall determine conformance to specification requirements. Take measurements at minor diameter (Reading No. 1) on the thread crest bisector to determine base material hardness. Take measurements (Reading No. 2) on the bisector 0.75 h, from the minor measurement toward the thread crest. Also take measurements (Reading No. 3) on the thread flank at the pitch line at a depth within 0.08 mm from the surface. Reading No. 3 may be taken on the same or an adjacent thread.

11.4.4 Interpret Microhardness Readings as Follows:

11.4.4.1 A decrease of more than 30 hardness points from Reading No. 1 to Reading No. 2 shall be regarded as decarburization and indicates the screw does not conform to specification requirements.

11.4.4.2 An increase of more than 30 hardness points from Reading No. 1 to Reading No. 3 shall be regarded as carburization and indicates that the screw does not conform to specification requirements.

12. Inspection

12.1 The inspector representing the purchaser, upon reasonable notice, shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser’s representative shall be made before shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

14. Certification

14.1 Upon request for the purchaser in the contract or order, a manufacturer’s certification that the material was manufactured and tested in accordance with this specification, together with a report of the latest mechanical tests of each stock size in each shipment, shall be furnished at the time of shipment.

15. Responsibility

15.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

16. Packaging and Package Marking

16.1 Packaging:

16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

16.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

16.2 Package Marking:

16.2.1 Each shipping unit shall include or be plainly marked with the following information:

16.2.1.1 ASTM designation,
16.2.1.2 Name and brand or trademark of the manufacturer,
16.2.1.3 Number of pieces,
16.2.1.4 Purchase order number, and
16.2.1.5 Country of origin.

17. Keywords

17.1 alloy; metric; screws; set; socket; steel

SUMMARY OF CHANGES

This section identifies the location of selected changes to this standard that have been incorporated since the -99 issue. For the convenience of the user, Committee F16 has highlighted those changes that impact the use of this standard. This section may also include descriptions of the changes or reasons for the changes, or both.


The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org).
1. Scope *

1.1 This specification covers the requirements for compressible-washer-type direct tension indicators capable of indicating the achievement of a specified minimum bolt tension in a structural bolt.

1.2 Two types of direct tension indicators in nominal diameter sizes 1⁄2 through 1 1⁄2 in. are covered:

1.2.1 Type 325—direct tension indicators for use with Specification A 325 bolts, and

1.2.2 Type 490—direct tension indicators for use with Specification A 490 bolts.

1.3 Direct tension indicators are intended for installation under either a bolt head or a hardened washer. (See Research Council on Structural Connections: Specification for Structural Joints Using ASTM A 325 or A 490 Bolts.)

1.4 The following precautionary statement pertains only to the test method portions, Section 12 and Appendix X1 of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

- A 325 Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
- A 490 Specification for Heat-Treated Steel Structural Bolts, 150 ksi Minimum Tensile Strength
- B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
- D 3951 Practice for Commercial Packaging

2.2 Research Council on Structural Connections: Specification for Structural Joints Using ASTM A 325 or A 490 Bolts

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 compressible-washer-type direct tension indicator, n—a washer-type element inserted under the bolt head or hardened washer, having the capability of indicating the achievement of a required minimum bolt tension by the degree of direct tension indicator plastic deformation. Hereafter referred to as direct tension indicator.

4. Ordering Information

4.1 Orders for direct tension indicators under this specification shall include the following:

4.1.1 Quantity (number of pieces);
4.1.2 Name of product (direct tension indicator);
4.1.3 Size, that is, nominal diameter;
4.1.4 ASTM designation and year of issue (if not specified, current issue shall be used);
4.1.5 Type required, 325 or 490 (1.2);
4.1.6 Coating type, if required (5.4);

5 Available from Research Council on Structural Connections at www.boltcouncil.org.

*A Summary of Changes section appears at the end of this standard.
4.1.7 Source inspection, if required (Section 13);  
4.1.8 Certificates of compliance or test reports, if required  
(Section 15); and  
4.1.9 Any special requirements.

5. Materials and Manufacture

5.1 Steel used in the manufacture of direct tension indicators shall be produced by the basic-oxygen or electric-furnace process.

5.2 **Design:**

5.2.1 Direct tension indicators shall have a configuration produced by extrusion, punching, pressing, or similar forming, to permit a measurable decrease in thickness when placed in compression.

5.2.2 The design shall be such that the degree of plastic deformation shall indicate the tension in a tightened structural bolt.

5.3 **Heat Treatment**—The process used for heat treatment of DTIs shall be through-hardening by heating to a temperature above the upper transformation temperature, quenching in a liquid medium, and then retempering by reheating to a suitable temperature to attain desired mechanical/performance properties.

5.4 **Protective Coatings:**

5.4.1 Unless otherwise specified, the direct tension indicators shall be furnished “plain” with the “as fabricated” surface finish without protective coatings.

5.4.2 When “zinc coated” is specified, the direct tension indicators shall be zinc coated by the mechanical deposition process in accordance with the requirements of Class 50 of Specification B 695.

5.4.3 When “baked epoxy” is specified, the epoxy shall be 0.001 to 0.002 in. thick applied over the zinc coating specified in 5.4.2. The epoxy shall not flake off exposed surfaces during installation.

5.4.4 Other coatings are to be used only when approved by the direct tension indicator manufacturer.

6. Chemical Composition

6.1 The direct tension indicators shall conform in chemical composition to the limits given in Table 1.

6.2 Product analysis may be made by the purchaser from finished direct tension indicators representing each lot. The chemical composition shall conform to the requirements given in Table 1, Product Analysis.

7. Performance Requirements

7.1 **Compression Loads**—When compressed to the gap specified in Table 2, the compression load shall conform to the requirements specified in Table 3.

8. Dimensions

8.1 The direct tension indicators shall conform to the dimensions specified in Table 4.

9. Workmanship, Finish, and Appearance

9.1 The direct tension indicators shall be commercially smooth and free of injurious material or manufacturing defects that would affect their performance.

10. Number of Tests and Retests

10.1 **Responsibility:**

10.1.1 The direct tension indicator manufacturer shall inspect each lot of direct tension indicators prior to shipment in accordance with the quality assurance procedures described in 10.2.

10.1.2 The purpose of a lot inspection testing program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective, it is essential that the purchaser continue to maintain the identification and integrity of each lot following delivery until the product is installed in its service application.

10.2 **Production Lot Method:**

10.2.1 All direct tension indicators shall be processed in accordance with a lot identification control–quality assurance plan. The manufacturer shall identify and maintain the integrity of each production lot of direct tension indicators from raw material selection through all processing operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

10.2.2 For purposes of assigning an identification number and from which test samples shall be selected, a production lot shall consist of all direct tension indicators processed essentially together through all operations to placing in the shipping

## Table 1: Chemical Requirements

<table>
<thead>
<tr>
<th>Element</th>
<th>Composition, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heat Analysis</td>
</tr>
<tr>
<td>Carbon</td>
<td>0.30–0.50</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.50–0.90</td>
</tr>
<tr>
<td>Phosphorus,</td>
<td>0.035</td>
</tr>
<tr>
<td>Max</td>
<td>0.040</td>
</tr>
<tr>
<td>Sulfur, Max</td>
<td>0.15–0.35</td>
</tr>
<tr>
<td>Silicon</td>
<td></td>
</tr>
</tbody>
</table>

## Table 2: Direct Tension Indicator Gap for Compression Load Testing

<table>
<thead>
<tr>
<th>Direct Tension Indicator Finish</th>
<th>Specification A 325</th>
<th>Specification A 490</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain finish</td>
<td>0.015</td>
<td>0.015</td>
</tr>
<tr>
<td>Mechanically galvanized</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>Baked epoxy coating on</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mechanically deposited zinc</td>
<td>0.015</td>
<td></td>
</tr>
</tbody>
</table>

## Table 3: Acceptable Range of Compression Loads

<table>
<thead>
<tr>
<th>Direct Tension Indicator Size (bolt diameter, (in.))</th>
<th>Compression Load Range in Thousands of Pounds, (kips)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 325</td>
<td>1⁄8: 12–14, 15–18</td>
</tr>
<tr>
<td></td>
<td>5⁄16: 19–23, 24–29</td>
</tr>
<tr>
<td></td>
<td>3⁄8: 28–34, 35–42</td>
</tr>
<tr>
<td></td>
<td>7⁄16: 39–47, 49–59</td>
</tr>
<tr>
<td></td>
<td>1: 51–61, 64–77</td>
</tr>
<tr>
<td></td>
<td>1 1⁄4: 56–67, 80–96</td>
</tr>
<tr>
<td></td>
<td>1 1⁄8: 71–85, 102–122</td>
</tr>
<tr>
<td></td>
<td>1 1⁄4: 85–102, 121–145</td>
</tr>
<tr>
<td></td>
<td>1 1⁄2: 103–124, 148–178</td>
</tr>
</tbody>
</table>
container that are of the same nominal size, produced from the same mill heat of steel, and heat treated in the same heat treatment cycle.

10.2.3 The minimum number of samples to be tested to determine compression loads and coating thickness (when applicable) shall be in accordance with the requirements specified in Guide F 1470.

10.3 Number of Tests After Alterations—if direct tension indicators are heat treated, coated, or otherwise altered by a subcontractor or manufacturer subsequent to testing, they shall be tested in accordance with 10.2 prior to shipment to the purchaser after all alterations have been completed.

11. Specimen Preparation

11.1 Indicators for tests shall be tested full size “as received” without any special preparation.

12. Test Methods

12.1 Compression load tests shall be conducted in accordance with Test Methods F 606.

13. Inspection

13.1 If the inspection described in 13.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

13.2 The purchaser’s quality assurance representative shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the direct tension indicators ordered. The manufacturer shall afford the quality assurance representative all reasonable facilities to satisfy him that the direct tension indicators are being furnished in accordance with this specification. All tests and inspections required by this specification that are requested by the purchaser’s representative shall be made before shipment and shall be conducted so as not to interfere unnecessarily with the operation of the plant.

14. Rejection

14.1 Direct tension indicators that fail to conform to the requirements of this specification shall be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

15. Certification

15.1 When specified on the order, the manufacturer shall furnish a test report as described in 15.2 or a certificate of compliance as described in 15.3, whichever is required.

15.2 When test reports are required, the manufacturers shall furnish a test report for each production lot from which direct tension indicators are supplied to fill a shipment. The report shall show the heat number (to ensure that the chemical composition is on record and could be furnished upon request), compression test loads, measured thickness of protective coatings, gap, nominal size, production lot identification number, ASTM designation, type and issue date, and purchase order number.

15.3 When certificates of compliance are required, the manufacturer shall furnish a certificate certifying that the indicators have been manufactured and tested and conform to the requirements of this specification. The certificate shall show the production lot identification number, nominal size, ASTM designation, type and issue date, and purchase order number.

16. Responsibility

16.1 The party responsible for the direct tension indicator shall be the organization that supplies the direct tension indicator to the purchaser and certifies that the direct tension indicator was manufactured, sampled, tested, and inspected in accordance with this specification and meets all of its requirements.

17. Product Marking

17.1 Each direct tension indicator shall be marked to identify the lot number, manufacturer or private label distribution, as appropriate, and type (see 1.2).

17.2 All markings shall be depressed on the same face of the direct tension indicators as the protrusions. Raised markings are prohibited.

18. Packaging and Package Marking

18.1 Packaging:

18.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

18.1.2 Packaging shall be performed as soon as is practical following final testing.

---

**TABLE 4 Dimensions of Direct Tension Indicators**

<table>
<thead>
<tr>
<th>Direct Tension Indicator Size (nominal diameter, in.)</th>
<th>Type 325</th>
<th></th>
<th>Type 490</th>
<th></th>
<th>All Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside Diameter (OD), in.</td>
<td>Number of Protrusions (equally spaced)</td>
<td>Thickness, in.</td>
<td>Number of Protrusions (equally spaced)</td>
<td>Thickness, in.</td>
<td>Inside Diameter (ID), in.</td>
</tr>
<tr>
<td>min</td>
<td>max</td>
<td>Without Protrusion min</td>
<td>With Protrusion max</td>
<td>min</td>
<td>max</td>
</tr>
<tr>
<td>1/8</td>
<td>1.167</td>
<td>1.187</td>
<td>4</td>
<td>0.104</td>
<td>0.180</td>
</tr>
<tr>
<td>3/16</td>
<td>1.355</td>
<td>1.375</td>
<td>4</td>
<td>0.126</td>
<td>0.220</td>
</tr>
<tr>
<td>1/4</td>
<td>1.605</td>
<td>1.625</td>
<td>5</td>
<td>0.126</td>
<td>0.220</td>
</tr>
<tr>
<td>5/32</td>
<td>1.855</td>
<td>1.875</td>
<td>5</td>
<td>0.142</td>
<td>0.240</td>
</tr>
<tr>
<td>3/8</td>
<td>1.980</td>
<td>2.000</td>
<td>6</td>
<td>0.158</td>
<td>0.270</td>
</tr>
<tr>
<td>1/2</td>
<td>2.230</td>
<td>2.250</td>
<td>6</td>
<td>0.158</td>
<td>0.270</td>
</tr>
<tr>
<td>5/32</td>
<td>2.480</td>
<td>2.500</td>
<td>7</td>
<td>0.158</td>
<td>0.270</td>
</tr>
<tr>
<td>3/8</td>
<td>2.730</td>
<td>2.750</td>
<td>7</td>
<td>0.158</td>
<td>0.270</td>
</tr>
<tr>
<td>1/2</td>
<td>2.980</td>
<td>3.000</td>
<td>8</td>
<td>0.158</td>
<td>0.270</td>
</tr>
</tbody>
</table>

---

* Nominal direct tension indicator sizes are intended for use with fasteners of the same nominal diameter.
18.1.3 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

18.2 Package Marking:
18.2.1 Each shipping unit shall include or be marked plainly with the following information:
   18.2.1.1 ASTM designation and type,
   18.2.1.2 Size,
   18.2.1.3 Name and brand or trademark of the manufacturer or private label distributor,
   18.2.1.4 Number of pieces,
   18.2.1.5 Purchase order number,
   18.2.1.6 Name of product,
   18.2.1.7 Lot identification number,
   18.2.1.8 Finish, and
   18.2.1.9 Country of origin.

19. Storage
19.1 The direct tension indicators shall be stored in an environment that preserves the surface condition supplied by the manufacturer.

20. Keywords
   20.1 compressible-washer-type; direct tension indicators; DTI; indicators

APPENDIX
(Nonmandatory Information)

X1. FIELD TESTING OF DIRECT TENSION INDICATORS FOR BOLT TENSION

DTIs may be field tested in a bolt tension calibrator with bolts, nuts, and flat washers, according to the provisions of the Research Council of Structural Connections Specification for Structural Joints Using A 325 or A 490 Bolts to determine a job inspection gap. The job inspection gap shall be a gap less than the measured DTI test gap at 1.05\times the minimum required bolt tension.

Because bolt tension calibrators are “soft” devices, unlike hard steel connections, care should be taken to tension the bolts with a non-impacting wrench so the tension readings can be recorded exactly.

SUMMARY OF CHANGES

This section contains the principal changes to the standard that have been incorporated since the last issue.

Standard Specification for Compressible-Washer-Type Direct Tension Indicators for Use With Structural Fasteners [Metric] ¹

This standard is issued under the fixed designation F 959M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers the requirements for compressible-washer-type direct tension indicators capable of indicating the achievement of a specified minimum bolt tension in a structural bolt.

1.2 Two types of direct tension indicators in nominal diameter sizes M16 through M36 are covered:

1.2.1 Type 8.8—direct tension indicators for use with Specification A 325M bolts, and

1.2.2 Type 10.9—direct tension indicators for use with Specification A 490M bolts.

1.3 Direct tension indicators are intended for installation under either a bolt head or a hardened washer. (See Research Council on Structural Connections: Specification for Structural Joints Using ASTM A 325 or A 490 Bolts.)

1.4 The following precautionary statement pertains only to the test methods portions, Section 12, and Appendix X1 of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

A 325M Specification for Structural Bolts, Steel, Heat-Treated, 120/105 ksi Minimum Tensile Strength [Metric] ²
A 490M Specification for High-Strength Steel Bolts, Classes 10.9 and 10.9.3, for Structural Steel Joints [Metric] ²
B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel ²
D 3951 Practice for Commercial Packaging ³

F 606M Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets [Metric]
F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection ²

2.2 Research Council on Structural Connections Standard: Specification for Structural Joints Using ASTM A 325 or A 490 Bolts ⁴

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 compressible-washer-type direct tension indicator, n—a washer-type element inserted under the bolt head or hardened washer, having the capability of indicating the achievement of a required minimum bolt tension by the degree of direct tension indicator plastic deformation. Hereafter referred to as direct tension indicator.

4. Ordering Information

4.1 Orders for direct tension indicators under this specification shall include the following:

4.1.1 Quantity (number of pieces);
4.1.2 Name of product (direct tension indicator);
4.1.3 Size, that is, nominal diameter;
4.1.4 ASTM designation and year of issue (if not specified, current issue shall be used);
4.1.5 Type required, 8.8 or 10.9 (see 1.2);
4.1.6 Coating type, if required (see 5.4);
4.1.7 Source inspection, if required (Section 13);
4.1.8 Certificates of compliance or test reports, if required (Section 15); and
4.1.9 Any special requirements.

5. Materials and Manufacture

5.1 Steel used in the manufacture of direct tension indicators shall be produced by the basic-oxygen or electric-furnace process.

¹ A Summary of Changes section appears at the end of this standard.

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5.2 Design:
5.2.1 Direct tension indicators shall have a configuration produced by extrusion, punching, pressing, or similar forming, to permit a measurable decrease in thickness when placed in compression.
5.2.2 The design shall be such that the degree of plastic deformation shall indicate the tension in a tightened structural bolt.

5.3 Heat Treatment—The process used for heat treatment of DTIs shall be through-hardening by heating to a temperature above the upper transformation temperature, quenching in a liquid medium, and then retempering by reheating to a suitable temperature to attain desired mechanical/performance properties.

5.4 Protective Coatings:
5.4.1 Unless otherwise specified, the direct tension indicators shall be furnished “plain,” with the “as fabricated” surface finish without protective coatings.
5.4.2 When “zinc coated” is specified, the direct tension indicators shall be zinc coated by the mechanical deposition process in accordance with the requirements of Class 50 of Specification B 695.
5.4.3 When “baked epoxy” is specified, the epoxy shall be 0.025 to 0.05 mm thick applied over the zinc coating specified in 5.4.2. The epoxy shall not flake off exposed surfaces during installation.
5.4.4 Other coatings are to be used only when approved by the direct tension indicator manufacturer.

6. Chemical Composition
6.1 The direct tension indicators shall conform in chemical composition to the limits given in Table 1.
6.2 Product analysis may be made by the purchaser from finished direct tension indicators representing each lot. The chemical composition shall conform to the requirements given in Table 1, Product Analysis.

7. Performance Requirements
7.1 Compression Loads—When compressed to the gap specified in Table 2, the compression load shall conform to the requirements specified in Table 3.

8. Dimensions
8.1 The direct tension indicators shall conform to the dimensions specified in Table 4.

### TABLE 1 Chemical Requirements

<table>
<thead>
<tr>
<th>Element</th>
<th>Composition, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heat Analysis</td>
</tr>
<tr>
<td>Carbon</td>
<td>0.30–0.50</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.50–0.90</td>
</tr>
<tr>
<td>Phosphorus, max</td>
<td>0.035</td>
</tr>
<tr>
<td>Sulfur, max</td>
<td>0.040</td>
</tr>
<tr>
<td>Silicon</td>
<td>0.15–0.35</td>
</tr>
</tbody>
</table>

### TABLE 2 Direct Tension Indicator Gap for Compression Load Testing

<table>
<thead>
<tr>
<th>Direct Tension Indicator Finish</th>
<th>Gap, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specification</td>
<td></td>
</tr>
<tr>
<td>8.8</td>
<td></td>
</tr>
<tr>
<td>Specification</td>
<td></td>
</tr>
<tr>
<td>10.9</td>
<td></td>
</tr>
<tr>
<td>Plain finish</td>
<td>0.4</td>
</tr>
<tr>
<td>Mechanically galvanized</td>
<td>0.4</td>
</tr>
<tr>
<td>Baked epoxy coating on</td>
<td></td>
</tr>
<tr>
<td>Mechanically deposited zinc</td>
<td>0.4</td>
</tr>
</tbody>
</table>

### TABLE 3 Acceptable Range of Compression Loads

<table>
<thead>
<tr>
<th>Direct Tension Indicator Size</th>
<th>Compression Load Range, kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Nominal Diameter, mm)</td>
<td>Type 8.8</td>
</tr>
<tr>
<td>M16</td>
<td>91–109</td>
</tr>
<tr>
<td>M20</td>
<td>142–170</td>
</tr>
<tr>
<td>M22</td>
<td>176–211</td>
</tr>
<tr>
<td>M24</td>
<td>205–246</td>
</tr>
<tr>
<td>M27</td>
<td>267–320</td>
</tr>
<tr>
<td>M30</td>
<td>326–391</td>
</tr>
<tr>
<td>M36</td>
<td>475–570</td>
</tr>
</tbody>
</table>

9. Workmanship, Finish, and Appearance
9.1 The direct tension indicators shall be commercially smooth and free of injurious material or manufacturing defects that would affect their performance.

10. Number of Tests and Retests
10.1 Responsibility:
10.1.1 The direct tension indicator manufacturer shall inspect each lot of direct tension indicators prior to shipment in accordance with the quality assurance procedures described in 10.2.
10.1.2 The purpose of a lot inspection testing program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective, it is essential that the purchaser continue to maintain the identification and integrity of each lot following delivery until the product is installed in its service application.

10.2 Production Lot Method:
10.2.1 All direct tension indicators shall be processed in accordance with a lot identification control–quality assurance plan. The manufacturer shall identify and maintain the integrity of each production lot of direct tension indicators from raw material selection through all processing operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.
10.2.2 For purposes of assigning an identification number and from which test samples shall be selected, a production lot, shall consist of all direct tension indicators processed essentially together through all operations to placing in the shipping container that are of the same nominal size, produced from the same mill heat of steel, and heat treated in the same heat treatment cycle.
10.2.3 The minimum number of samples to be tested to determine compression loads and coating thickness (when applicable) shall be in accordance with the requirements specified in Guide F 1470.
10.3 Number of Tests After Alterations—If direct tension indicators are heat treated, coated, or otherwise altered by a subcontractor or manufacturer subsequent to testing, they shall be tested in accordance with 10.2 prior to shipment to the purchaser after all alterations have been completed.

11. Specimen Preparation

11.1 Indicators for tests shall be tested full size "as received," without any special preparation.

11.2 All test specimens shall conform to the values given in Table 3, regardless of surface coating (lubricants included).

12. Test Methods

12.1 Direct tension indicators shall be tested in accordance with F 606M.

13. Inspection

13.1 If the inspection described in 13.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

13.2 The purchaser’s quality assurance representative shall have free entry to all parts of the manufacturer’s works that concern the manufacture of the direct tension indicators ordered. The manufacturer shall afford the quality assurance representative all reasonable facilities to satisfy him that the direct tension indicators are being furnished in accordance with this specification. All tests and inspections required by this specification that are requested by the purchaser’s representative shall be made before shipment and shall be conducted so as not to interfere unnecessarily with the operation of the plant.

14. Rejection

14.1 Direct tension indicators that fail to conform to the requirements of this specification shall be rejected. Rejection shall be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

15. Certification

15.1 When specified on the order, the manufacturer shall furnish a test report as described in 15.2 or a certificate of compliance as described in 15.3, whichever is required.

15.2 When test reports are required, the manufacturers shall furnish a test report for each production lot from which direct tension indicators are supplied to fill a shipment. The report shall show the heat number (to ensure that the chemical composition is on record and could be furnished upon request), compression test loads, measured thickness of protective coatings, gap, nominal size, production lot identification number, ASTM designation, type and issue date, and purchase order number.

15.3 When certificates of compliance are required, the manufacturer shall furnish a certificate certifying that the indicators have been manufactured and tested and conform to the requirements of this specification. The certificate shall show the production lot identification number, nominal size, ASTM designation, type and issue date, and purchase order number.

16. Responsibility

16.1 The party responsible for the direct tension indicator shall be the organization that supplies the direct tension indicator to the purchaser and certifies that the direct tension indicator was manufactured, sampled, tested, and inspected in accordance with this specification and meets all of its requirements.

17. Product Marking

17.1 Each direct tension indicator shall be marked to identify the lot number; manufacturer or private label distribution, as appropriate; and type (see 1.2).

17.2 All markings shall be depressed on the same face of the direct tension indicators as the protrusions. Raised markings are prohibited.

17.3 All direct tension indicators shall have circumferential indentations spaced equally around the outside circumference, corresponding to and in alignment with each feeler gage entry space. Indentations shall be clearly visible but not so large as to interfere with the function of the direct tension indicator. (See Fig. 1).

17.3.1 The circumferential indentations indicate where the feeler gage must be inserted.

18. Packaging and Package Marking

18.1 Packaging:

---

**TABLE 4 Dimensions of Direct Tension Indicators**

<table>
<thead>
<tr>
<th>Direct Tension Indicator Size (Nominal Diameter, mm)</th>
<th>Type 8.8</th>
<th>All Types</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Outside Diameter (OD), mm</td>
<td>Number of Protrusions (Equally Spaced)</td>
</tr>
<tr>
<td>M16</td>
<td>min</td>
<td>max</td>
</tr>
<tr>
<td></td>
<td>38.8</td>
<td>36.2</td>
</tr>
<tr>
<td>M20</td>
<td>46.0</td>
<td>44.0</td>
</tr>
<tr>
<td>M22</td>
<td>50.6</td>
<td>48.4</td>
</tr>
<tr>
<td>M24</td>
<td>55.2</td>
<td>52.8</td>
</tr>
<tr>
<td>M27</td>
<td>62.1</td>
<td>59.4</td>
</tr>
<tr>
<td>M30</td>
<td>69.0</td>
<td>66.0</td>
</tr>
<tr>
<td>M36</td>
<td>82.8</td>
<td>79.2</td>
</tr>
</tbody>
</table>

**Note:** Nominal direct tension indicator sizes are intended for use with fasteners of the same nominal diameter.
18.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

18.1.2 Packaging shall be performed as soon as is practical following final testing.

18.1.3 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

18.2 Package Marking:

18.2.1 Each shipping unit shall include or be marked plainly with the following information:

18.2.1.1 ASTM designation and type,

18.2.1.2 Size,

18.2.1.3 Name and brand or trademark of the manufacturer or private label distributor,

18.2.1.4 Number of pieces,

18.2.1.5 Purchase order number,

18.2.1.6 Name of product,

18.2.1.7 Lot identification number,

18.2.1.8 Finish, and

18.2.1.9 Country of origin.

19. Storage

19.1 The direct tension indicators shall be stored in an environment that preserves the surface condition supplied by the manufacturer.

20. Keywords

20.1 compressible-washer-type; direct tension indicators; DTI; indicators

APPENDIX

(Nonmandatory Information)

XI. FIELD TESTING OF DIRECT TENSION INDICATORS FOR BOLT TENSION

DTIs may be field tested in a bolt tension calibrator with bolts, nuts, and flat washers, according to the provisions of the Research Council on Structural Connections Specification for Structural Joints Using A 325 or A 490 Bolts to determine a job inspection gap. The job inspection gap shall be a gap less than the measured DTI test gap at $1.05 \times$ the minimum required bolt tension.

Because bolt tension calibrators are “soft” devices, unlike hard steel connections, care should be taken to tension the bolts with a non-impacting wrench so the tension readings can be recorded exactly.

SUMMARY OF CHANGES

This section contains the principal changes to the standard that have been incorporated since the last issue.

Standard Guide for Selection of Committee F16 Fastener Specifications

This standard is issued under the fixed designation F 1077; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide is intended to provide a rapid, easy to use method for identifying Committee F16 fastener specifications and their applicable marking requirements. Selection is made by product type (bolts, nuts, washers, etc.) and material (alloy steel, carbon steel, stainless steel, etc.) from Tables 1-5 as follows:

<table>
<thead>
<tr>
<th>Table Number</th>
<th>In</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrous Metals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alloy Steel</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Carbon Steel</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Weathering Steel</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Non Ferrous</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminum, Copper</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Nickel, Titanium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stainless Steels</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Others</td>
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<td></td>
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<tr>
<td>Coatings, Definitions, Test Methods, Surface Discontinuities</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Marking</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

1.2 Table size limitations and the need for simplicity prohibit identifying the exact grade, type, condition, etc., for all product/material combinations. The product specification must be reviewed prior to specifying fasteners on drawings or ordering to properly and completely identify the fastener, and its available variations.

2. Referenced Documents

2.1 ASTM Standards:
A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
A 394 Specification for Steel Transmission Tower Bolts, Zinc-Coated and Bare
A 449 Specification for Quenched and Tempered Steel Bolts and Studs
A 489 Specification for Carbon Steel Lifting Eyes
A 490 Specification for Structural Bolts, Alloy Steel, Heat Treatment, 150 ksi Minimum Tensile Strength
A 490M Specification for High-Strength Steel Bolts, Classes 10.9 and 10.9.3, for Structural Steel Joints [Metric]
A 502 Specification for Steel Structural Rivets
A 563 Specification for Carbon and Alloy Steel Nuts
A 563M Specification for Carbon and Alloy Steel Nuts [Metric]
A 574 Specification for Alloy Steel Socket-Head Cap Screws
A 574M Specification for Alloy Steel Socket-Head Cap Screws [Metric]
A 687 Specification for High-Strength Nonheaded Steel Bolts and Studs
C 514 Specification for Nails for the Application of Gypsum Board
F 432 Specification for Roof and Rock Bolts and Accessories
F 436 Specification for Hardened Steel Washers
F 436M Specification for Hardened Steel Washers [Metric]
F 467 Specification for Nonferrous Nuts for General Use
F 467M Specification for Nonferrous Nuts for General Use [Metric]
F 468 Specification for Nonferrous Bolts, Hex Cap Screws, and Studs for General Use
F 541 Specification for Alloy Steel Eyebolts
F 547 Terminology of Nails for Use with Wood and Wood-Base Materials
F 568M Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners [Metric]

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2 Annual Book of ASTM Standards, Vol 01.08.
3 Discontinued–see 1998 Annual Book of ASTM Standards, Vol 01.08.
4 Annual Book of ASTM Standards, Vol 04.01.
### TABLE 1  Alloy, Carbon, and Weathering Steels, Inch

<table>
<thead>
<tr>
<th>Product</th>
<th>Alloy Steel</th>
<th>Carbon Steel</th>
<th>Weathering Steels</th>
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<tbody>
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<td></td>
<td></td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Bolts</strong></td>
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<td></td>
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<tr>
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<td></td>
<td></td>
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<tr>
<td>Eye</td>
<td>F 541</td>
<td>A 489</td>
<td></td>
</tr>
<tr>
<td>UT 60K</td>
<td>A 307 Gr A, B</td>
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<td></td>
</tr>
<tr>
<td>UT 120, 105, 90K</td>
<td>A 449 Type 1</td>
<td>A 449 Type 2</td>
<td></td>
</tr>
<tr>
<td>UT 125, 115K</td>
<td>A 354 Gr BC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UT 150, 140K</td>
<td>A 354 Gr BD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non Headed</td>
<td>A 687</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof and Rock</td>
<td>F 432</td>
<td></td>
<td></td>
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<tr>
<td>Structural:</td>
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<td></td>
<td></td>
</tr>
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<td>UT 120, 105K</td>
<td>A 325 Type 1</td>
<td>A 325 Type 3</td>
<td></td>
</tr>
<tr>
<td>UT 150K</td>
<td>A 490 Type 1</td>
<td>A 490 Type 2</td>
<td>A 490 Type 3</td>
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<tr>
<td>Transmission tower</td>
<td>A 394 Type 0</td>
<td>A 394 Type 1</td>
<td>A 394 Type 2</td>
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<td><strong>Nails</strong></td>
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</tr>
<tr>
<td>Gypsum wallboard</td>
<td>C 514</td>
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<td><strong>Nuts</strong></td>
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<td>PL 69K</td>
<td>A 563 Gr B</td>
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<td>PL 100, 90K</td>
<td>A 563 Gr C</td>
<td>A 563 Gr D</td>
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<td>PL 133, 120, 116, 105K</td>
<td>A 563 Gr C</td>
<td>A 563 Gr D</td>
<td></td>
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<td>PL 144K</td>
<td>A 563 Gr C</td>
<td>A 563 Gr D</td>
<td></td>
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<td>PL 150, 135K</td>
<td>A 563 Gr C</td>
<td>A 563 Gr D</td>
<td></td>
</tr>
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<td>PL 175, 150K</td>
<td>A 563 Gr DH</td>
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<td>PL 175K</td>
<td>A 563 Gr DH</td>
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<td><strong>Rivets</strong></td>
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<td></td>
</tr>
<tr>
<td>General purpose</td>
<td>A 502 Gr 1</td>
<td>A 490 Type 1</td>
<td>A 490 Type 2</td>
</tr>
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<td>Pressure vessel</td>
<td>A 502 Gr 1</td>
<td>A 502 Gr 2</td>
<td>A 502 Gr 3</td>
</tr>
<tr>
<td>Structural</td>
<td>A 502 Gr 1</td>
<td>A 502 Gr 2</td>
<td>A 502 Gr 3</td>
</tr>
<tr>
<td><strong>Screws</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Hex cap</td>
<td>A 574</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Socket head</td>
<td>F 835</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Socket button and flat CSK</td>
<td>F 912</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Socket set</td>
<td>F 835</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Studs</strong></td>
<td></td>
<td></td>
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<tr>
<td>UTS 58-80K</td>
<td>A 307 Gr C</td>
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<tr>
<td>UTS 120, 105, 90K</td>
<td>A 449 Type 1</td>
<td>A 449 Type 2</td>
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<tr>
<td>UTS 125, 115K</td>
<td>A 354 Gr BC</td>
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<tr>
<td>UTS 150, 140K</td>
<td>A 354 Gr BD</td>
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<td>UTS 150K</td>
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<tr>
<td><strong>Washers</strong></td>
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</tr>
<tr>
<td>General Purpose, Soft</td>
<td>F 844</td>
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<td>General Purpose, Hard</td>
<td>F 436</td>
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<tr>
<td>Load Indicating</td>
<td>F 959 Type 490</td>
<td>F 959 Type 325</td>
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</tr>
<tr>
<td>Structural, Hard</td>
<td>F 436</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

*Abbreviations:

- UTS: Ultimate Tensile Strength
- PL: Proof Load
- A: American Society for Testing and Materials (ASTM)

*Note:

- Ultimate tensile strengths (UTS) and proof loads (PL) shown are approximations and vary with size. For break points, see applicable product specification.
- For bolt/nut suitability guide, see (A 563 Table X 1.1.).
- May be furnished as carbon, alloy, or carbon boron steel.

### TABLE 2  Aluminum, Copper, Nickel, Titanium, and Stainless Steels (Inch)

<table>
<thead>
<tr>
<th>Product</th>
<th>Aluminum&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Copper&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Nickel&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Titanium&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Stainless&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bolts</strong></td>
<td>General purpose</td>
<td>F 468</td>
<td>F 468</td>
<td>F 468</td>
<td>F 468</td>
</tr>
<tr>
<td>Transmission tower</td>
<td>F 901</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nuts</strong></td>
<td>General purpose</td>
<td>F 467</td>
<td>F 467</td>
<td>F 467</td>
<td>F 467</td>
</tr>
<tr>
<td>Transmission tower</td>
<td>F 901</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Rivets</strong></td>
<td>Hex cap</td>
<td>F 468</td>
<td>F 468</td>
<td>F 468</td>
<td>F 468</td>
</tr>
<tr>
<td>Socket head</td>
<td>F 468</td>
<td>F 468</td>
<td>F 468</td>
<td>F 468</td>
<td>F 593</td>
</tr>
<tr>
<td>Socket button and Flat CSK</td>
<td>F 468</td>
<td>F 468</td>
<td>F 468</td>
<td>F 468</td>
<td>F 593</td>
</tr>
<tr>
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<td>F 468</td>
<td>F 468</td>
<td>F 468</td>
<td>F 593</td>
</tr>
<tr>
<td><strong>Studs</strong></td>
<td>F 468</td>
<td>F 468</td>
<td>F 468</td>
<td>F 468</td>
<td>F 593</td>
</tr>
<tr>
<td><strong>Washers</strong></td>
<td>F 593</td>
<td>Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

*Abbreviations:

- F 592: Terminology of Collated and Cohered Fasteners and Their Application Tools<sup>2</sup>
- F 593: Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs<sup>2</sup>
### TABLE 3 Ferrous, Nonferrous, and Stainless Steel, Metric

<table>
<thead>
<tr>
<th>Product</th>
<th>Ferrous(^4)</th>
<th>Nonferrous(^4)</th>
<th>Stainless Steel(^4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bolts:</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>General purpose</td>
<td>F 568 Cl 12.9</td>
<td>F 568 Cl 4.6, 4.8, 5.8, 8.8, 9.8, 10.9</td>
<td>F 468M, F 738M</td>
</tr>
<tr>
<td>Structural:</td>
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<td></td>
</tr>
<tr>
<td>8.8, 8.8.3</td>
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<td>A 325M Type 1, 2</td>
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<td>10.9, 10.9.3</td>
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<td>A 490M Type 1, 2</td>
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<tr>
<td>Transmission tower</td>
<td></td>
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</tr>
<tr>
<td>Nuts</td>
<td>A 563M Cl 5.9, 8S, 10, 10S, 12</td>
<td>A 563M Cl 8S3, 10S3</td>
<td>F 467M, F 836M</td>
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<td><strong>Rivets</strong></td>
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<tr>
<td>Screws:</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Hex cap</td>
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<td>F 568 Cl 4.6, 4.8, 5.8, 8.8, 9.8, 10.9</td>
<td>F 468M, F 738M</td>
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<td>Heavy hex</td>
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<td>F 568 Cl 4.6, 4.8, 5.8, 8.8, 9.8, 10.9</td>
<td>F 568 Cl 8.8.3, 10.9.3</td>
<td>F 837M, F 879M</td>
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<td>Socket head</td>
<td>A 574M</td>
<td></td>
<td>F 837M</td>
</tr>
<tr>
<td>Socket button and Flat CSK</td>
<td>F 835M</td>
<td></td>
<td>F 879M</td>
</tr>
<tr>
<td><strong>Studs</strong></td>
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<td></td>
</tr>
<tr>
<td><strong>Nuts</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>A 574M</td>
<td>F 871M, F 1135, F 1136, F 1137</td>
<td>F 606</td>
<td>F 788</td>
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<tr>
<td><strong>Nails</strong></td>
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</tr>
<tr>
<td>A 563M</td>
<td>F 871M, F 1135, F 1136, F 1137</td>
<td>F 606</td>
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<td><strong>Rivets</strong></td>
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<td><strong>Screws</strong></td>
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<td>A 568M</td>
<td>F 871M, F 1135, F 1136, F 1137</td>
<td>F 606</td>
<td>F 788</td>
</tr>
<tr>
<td><strong>Studs</strong></td>
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<td>A 568M</td>
<td>F 871M, F 1135, F 1136, F 1137</td>
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<tr>
<td><strong>Washers</strong></td>
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<td>A 568M</td>
<td>F 871M, F 1135, F 1136, F 1137</td>
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<tr>
<td><strong>Hard</strong></td>
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<td>A 568M</td>
<td>F 871M, F 1135, F 1136, F 1137</td>
<td>F 606</td>
<td>F 788</td>
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</table>

\(^4\)See product specifications for available alloys.

### TABLE 4 Coatings, Test Methods, Definitions, and Surface Discontinuities

<table>
<thead>
<tr>
<th>Products</th>
<th>Coatings</th>
<th>Definitions</th>
<th>Test Methods</th>
<th>Surface Discontinuities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bolts</strong></td>
<td>F 871M, F 1135, F 1136, F 1137</td>
<td>F 606</td>
<td>F 788</td>
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<tr>
<td>Collated and cohered fasteners</td>
<td>F 592</td>
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<td>F 606</td>
<td>F 788</td>
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<td>Nuts</td>
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<td>F 812</td>
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<td>F 788</td>
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<td>A 31</td>
<td>A and B</td>
<td>rivets</td>
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<td>A</td>
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<td>&quot;307B&quot;</td>
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<td></td>
<td>C</td>
<td>studs</td>
<td>yes</td>
<td>&quot;307C&quot;</td>
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<td>In addition may have 3 radial lines 120° apart.</td>
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<td>3</td>
<td>bolts</td>
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<td>BC</td>
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<td>bolts over 2.5 in. and all sizes of all other Grade BD products</td>
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<tr>
<td>1</td>
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<td>3</td>
<td>bolts</td>
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<td>bolts</td>
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<td>2</td>
<td>studs, bolts</td>
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<td>1 and 2</td>
<td>eyebolts</td>
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<td>bolts</td>
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<td>rivets</td>
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<td>Not required but &quot;1&quot; may be used at manufacturers option</td>
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<td>0, A, B</td>
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<td>C</td>
<td>heavy hex nuts</td>
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<td>A 194 Grade 2 and 2H are acceptable alternatives. Such nuts are marked 2, 2B, 2H, or 2HB instead of the 3 circumferential marks.</td>
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<td>heavy hex nuts</td>
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<td>In addition may have other distinguishing marks indicating weathering type steel. The numeral 3 may appear more than once.</td>
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<tr>
<td>D</td>
<td>all nuts</td>
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<td>A 194 Grade 2 and 2H are acceptable alternatives. Such nuts are marked 2, 2B, 2H, or 2HB instead of the Grade Symbol “D”.</td>
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<td>A 194 Grade 2H is an acceptable alternative. Such nuts are marked 2H or 2HB instead of the Grade Symbol “DH”.</td>
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<td>hex nuts</td>
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<td>All</td>
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<td>5</td>
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<td>socket head cap screws</td>
<td>yes (Manufacturers use knurl patterns for identification)</td>
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<td>...</td>
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<td>non-headed bolts and studs</td>
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<td>F 432</td>
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<td>bolts 0.25 and larger</td>
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<td>bolts, all other sizes</td>
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<td>bolts 0.875 in.</td>
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<td>Bolts, hex cap screws, and studs</td>
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<td>Cu 270</td>
<td>Bolts, hex cap screws, and studs</td>
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**F 738M**
- all
- M4 and smaller
- no
- not required

**F 835 and F 835M**
- all
- socket button and flat CSK head cap screws
- no
- not required

**F 836M**
- all
- M4 and smaller
- no
- not required

12
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<th>ASTM Number</th>
<th>Grade, Type, or Alloy</th>
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<th>Product and Size</th>
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F 837M all socket head cap screws M4 and less yes Property Class A1-50, A1-70, or C1-110 as applicable not required

F 844 all washers no not required

F 879 all socket button head cap screws and socket flange head cap screws no not required

F 879M all socket button head cap screws and socket flange head cap screws M4 and less no Property Class A1-50 or A1-70 as applicable

F 880 and F 880M all socket set screws no not required

F 901 all bolts yes not required

F 912 and F 912M all socket set screws no not required

F 959 all tension indicators yes "325" or "490" as applicable
Standard Specification for
Cadmium or Zinc Chromate Organic Corrosion Protective
Coating for Fasteners

This standard is issued under the fixed designation F 1135; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope
1.1 This specification covers the basic performance require-
ments for an electrolytic or mechanical coating of cadmium or
zinc followed by a chromate and baked organic coating for ferrous and nonferrous fasteners.
1.2 There are eight grades available under this standard; four for zinc and four for cadmium.
1.3 This standard is intended primarily for fasteners such as
nuts, bolts, and screws that require corrosion protection.

2. Referenced Documents
2.1 ASTM Standards:
B 117 Test Method of Salt Spray (Fog) Testing
B 244 Test Method for Measurement of Thickness of An-
odic Coatings on Aluminum and of Other Nonconductive
Coatings on Nonmagnetic Basis Metals with Eddy-Current
Instruments
B 487 Test Method for Measurement of Metal and Oxide
Coating Thickness by Microscopical Examination of a
Cross Section
B 499 Test Method for Measurement of Coating Thickness
by the Magnetic Method: Nonmagnetic Coatings on Mag-
netic Basis Metals
B 633 Specification for Electrodeposited Coatings of Zinc
on Iron and Steel
B 695 Specification for Coatings of Zinc Mechanically
Deposited on Iron and Steel
B 696 Specification for Coatings of Cadmium Mechanically
Deposited
D 3359 Test Method for Measuring Adhesion by Tape Test
F 871M Specification for Electrodeposited Coatings on
Threaded Components [Metric]
F 1470 Guide for Fastener Sampling for Specified Mechani-
cal Properties and Performance Inspection
F 1940 Test Method for Process Control Verification to
Prevent Hydrogen Embrittlement in Plated or Coated
Fasteners

3. Classification
3.1 These coatings are classified into eight grades according
to the requirements shown in Table 1.

4. Ordering Information
4.1 Orders for material under this specification shall include
the following information:
4.1.1 Quantity of parts.
4.1.2 Grade required (see 3.1) and color code (see 5.4).
4.1.3 Any conditions or additions agreed upon by the
purchaser and the supplier.

5. Requirements
5.1 Parts supplied to this specification shall have a chromate
coating plus an organic coating applied to maintain adequate
salt spray protection. The coatings shall not chip, leach color,
or suffer color loss.
5.2 Substrate shall be either ferrous or nonferrous metal
fasteners.
5.3 The finish shall be a cured organic coating.
5.4 The appearance shall be either CLEAR (Color code A)
or BLACK (Color code B). Other colors may be specified by
the purchaser.
5.5 The gloss shall be described as medium.
5.6 The film properties shall have sufficient hardness
through curing at time of delivery to withstand normal han-
dling and shipping without marring.
5.7 Coating Thickness Measurement—The thickness shall
be determined by the method described in 8.1 and meet the
requirements of Table 1.
5.8 Organic Coating Determination—Any part with the
coating applied and properly cured shall exhibit no discolora-
tion after soaking in a 5 % trisodium phosphate solution for 5
min at room temperature, water rinsed, towel dried, and
subjected to 1 to 2 drops of a 5 % lead acetate solution on the
surface for 60 s. Those parts lacking both an organic
and chromate coating will have a color change after about 5 s.
5.9 Adhesion—Parts heated to 190°C for 30 min shall not
exhibit blistering, peeling, flaking, or plating which can be
removed by filament tape in accordance with Test Method D 3359.

5.10 Salt Spray Test—No part shall exhibit white corrosion or red rust on significant surfaces (as agreed upon between supplier and producer prior to ordering) after exposure for the minimum number of salt spray h shown in Table 1.

6. Process Method

6.1 It is not intended to limit the supplier as to the formula or method of coating or surface treatment except as indicated:

6.1.1 Cadmium and zinc processing shall be in accordance with the applicable ASTM coating specification. Good practices may be found in Specifications B 633 and B 695 for zinc, Specification B 696 for cadmium and in Specification F 871M for both zinc and cadmium.

6.2 The chemical activator (surface conditioner) used shall not cause hydrogen embrittlement of hardened steel fasteners.

6.3 It is recommended that ferrous fasteners susceptible to time-delayed fracture caused by the diffusion of hydrogen under stress be processed by mechanically coating, or if electroplated be processed in accordance with Test Method F 1940.

7. Test Methods

7.1 The coating thickness shall be determined by eddy-current, Test Method B 244; magnetic methods, Test Method B 499; or microscopic examination of cross sections taken perpendicular to significant surfaces, Test Method B 487 (see Calibration of Micrometer Eyepiece) or other means agreed upon by the supplier and the producer. For referee purposes, microexamination in accordance with Test Method B 487 shall be used.

7.2 The corrosion resistance shall be determined in accordance with Test Method B 117.

7.3 The adhesion test shall be performed in accordance with Test Method D 3359.

8. Inspection

8.1 Samples shall be taken in accordance with Guide F 1470.

8.2 Coatings on the threads of threaded fasteners shall not have an adverse effect on normal installation and removal practices.

8.3 Referee Thread Inspection—The following referee thread inspection may be utilized if the specified go-gage binds on the bolt, nut, or screw:

8.3.1 Bolts or Screws—Assemble a phosphate-coated test nut with the applicable 2B or 6H class thread down the full length of the thread. If the nut can be assembled the full distance, the coating is acceptable.

8.3.2 Nuts—Assemble a phosphate coated bolt or screw with the applicable 2A or 6g class thread for a minimum of one diameter through the nut. If the bolt or screw can be assembled the full distance, the coating is acceptable.

9. Rejection and Rehearing

9.1 Unless otherwise specified, any rejection based on tests specified herein and made by the purchaser shall be reported to the supplier as soon as practical after receipt of the product by the purchaser.
Standard Specification for Chromium/Zinc Corrosion Protective Coatings for Fasteners

This standard is issued under the fixed designation F 1136; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε1 Note—Section 2 was editorially updated in October 1998.

1. Scope

1.1 This specification covers the basic requirements for three grades of chromium/zinc inorganic coatings for threaded fasteners.

1.2 These coatings are applied by conventional dip-spin or dip-drain methods.

1.3 The coating process does not induce hydrogen embrittlement providing that the fasteners have not been pre-treated with an acid.

2. Referenced Documents

2.1 ASTM Standards:

B 117 Test Method of Salt Spray (Fog) Testing2

D 1000 Test Methods for Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications3

D 2247 Practice for Testing Water Resistance of Coatings in 100 % Relative Humidity4

F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection5

3. Classification

3.1 These coatings are classified into three grades according to the requirements in Table 1.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Quantity of parts.

4.1.2 Grade of coating.

4.1.3 Any additions to the specification as agreed upon by the purchaser and the supplier.

5. Requirements

5.1 Appearance—The coating shall have a uniform appearance free from tears and other discontinuities which may affect the appearance or performance, or both, of the coating.

5.2 Adhesion—The coating shall show no evidence of blistering or other changes in appearance after exposure to humidity testing for a minimum of 96 h. In addition there shall be no more than 3.0 mm peel-back from the intersection of scribed lines that are taped tested immediately following a 10 min recovery period from the humidity test and there shall be no other peeling under tape (see 6.3 and 6.4).

5.3 Corrosion—These coatings shall be capable of withstanding neutral salt spray testing for the minimum h specified in Table 1. Unless otherwise defined, acceptable corrosion resistance shall be where there is no base metal corrosion on significant surfaces.

5.3.1 Significant surfaces are defined as the exposed surfaces of the fastener when it is installed in a normal manner. Surfaces on which a controlled deposit ordinarily cannot be obtained, such as holes, recesses, bases of angles, and similar areas are normally exempt from the requirements of significant surfaces.

5.4 Blisters—There shall be no signs of blisters after testing in accordance with 6.1 and 6.3.

5.5 Thread Fit—The coating shall not have an adverse affect on normal installation and removal practices as determined by the proper GO thread gauge. Excessive coating on the threaded surface may be acceptable only when the fastener passes the torque test outlined in 7.2.3.

5.5.1 The thickness of the coating is limited by the basic thread size. Where greater thickness is necessary the internal threads may be produced oversized (before coating) providing the finished product (after coating) meets all the specified mechanical properties. Where mechanical properties are not

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TABLE 1 Classification of Coatings

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<th>Grade</th>
<th>Chromium/Zinc Coating Weight, g/m²</th>
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<th>Thickness, µm</th>
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<tr>
<td>3</td>
<td>20.4–27.0</td>
<td>clear sealer</td>
<td>7.0–13.0</td>
<td>400</td>
</tr>
</tbody>
</table>
specified, oversizing is subject to the approval of the purchaser.

6. Test Methods

6.1 Corrosion—Corrosion resistance shall be tested in accordance with Test Method B 117.

6.2 Coating Thickness—The coating thickness may be determined by the microscopic examination of a cross section taken perpendicular to the significant surface or by the weigh-strip-weigh method.

Note 1—The weigh-strip-weigh method involves weighing the test specimen before and after the coating is stripped. The method requires a reagent that does not attack the base metal. Coating weight must be within the ranges given in Table 1.

6.3 Humidity Test—The humidity test shall be conducted in accordance with Practice D 2247 (100 % relative humidity at 100°F (38°C)).

6.4 Adhesion—Semi-transparent pressure sensitive tape with an adhesive strength of 400 ± N/m as tested in accordance with Test Methods D 1000 shall be used to test the adhesion of the coating. The adhesive characteristic of the tape shall not change by more than 5 % of its mean value within 12 months. The backing of the tape may consist of fiber-reinforced cellulose acetate, unplasticized poly vinyl chloride, or polyester film. When performing the adhesion test the tape shall be removed from the surface of the coated specimen with a sharp jerk.

7. Inspection

7.1 The purchaser may request samples in accordance with Guide F 1470.

7.2 Referee Inspection—The following referee thread inspection may be utilized if the specified go-gauge binds on the bolt, nut, or screw.

7.2.1 Bolt or Screws—Assemble a phosphate test nut with a 2B or 6H class thread down the full length of the thread.

7.2.2 Nut—Assemble a phosphate bolt or screw with a 2A or 6g class thread for a minimum of one diameter through the nut.

7.2.3 The test nut, screw, or bolt must run freely for the total length without binding. If nonuniformity of the coating causes difficulty in assembling the part, the coating may be found acceptable if it requires no more than a torque equivalent to 0.06D N-m to assemble the part.

8. Rejection

8.1 Materials that fail to conform to the requirements of this specification may be rejected.
Standard Specification for Phosphate/Oil and Phosphate/Organic Corrosion Protective Coatings for Fasteners

This standard is issued under the fixed designation F 1137; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the basic requirements for seven grades of corrosion protection for fasteners. Grade 0A consists of a zinc phosphate coating with no additional sealer (dry), Grade 0B consists of a zinc phosphate coating with a dry organic sealer, Grade 0C, Grade 0D, and Grade I consist of a zinc phosphate coating with supplemental protective oil type compound, and Grades II and III consist of a zinc phosphate with a supplemental zinc-rich epoxy resin coating (Grade II includes a clear organic topcoat).

1.2 This specification is intended primarily for fasteners such as nuts, clips, washers, and other ferrous threaded and non-threaded fasteners that require corrosion protection.

1.3 These coatings may or may not have a decorative finish.

2. Referenced Documents

2.1 ASTM Standards:

B 117 Practice for Operating Salt Spray (Fog) Apparatus
D 2247 Practice for Testing Water Resistance of Coatings in 100 % Relative Humidity
D 3359 Test Methods for Measuring Adhesion by Tape Test
F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

3. Classification

3.1 The zinc phosphate treatment and subsequent protective coatings are classified into seven grades according to the requirements shown in Table 1. Phosphate bath concentrations, temperatures and immersion times recommended by the chemical manufacture should be followed.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Quantity of parts, Grade required (see Table 1), and Any additions agreed upon between the purchaser and the supplier.

5. Requirements

5.1 Appearance—Unless otherwise agreed upon between the purchaser and the producer, the color of the protective coating shall be as-coated gray for Grades 0A, 0B, 0C, and 0D, black for Grade I, and metallic gray for Grades II and III. In addition, Grades II and III shall be free from tears, sags, and excess coating that may affect appearance or performance, or both.

5.2 Adhesion—The coating for Grades II and III shall show no evidence of blistering nor other appearance changes after exposure to humidity testing for 96-h minimum. It shall show no more than 3.0-mm peal-back from intersection of lines scribed and tape tested immediately after a 10-min recovery period following exposure, and no other peeling in area under the tape.

5.3 Corrosion Resistance—These coatings shall be capable of withstanding neutral salt spray for the minimum h specified in Table 1 with no base metal corrosion on significant surfaces.

---

TABLE 1 Classification and Performance Requirements of Protective Coatings

<table>
<thead>
<tr>
<th>Grade No.</th>
<th>Zinc Phosphate, g/m²</th>
<th>Supplemental Coating</th>
<th>Coating Thickness, µm</th>
<th>Salt Spray, h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 0A</td>
<td>11, min</td>
<td>none</td>
<td>see 5.5</td>
<td>72&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Grade 0B</td>
<td>11, min</td>
<td>sealer</td>
<td>see 5.5</td>
<td>72&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Grade 0C</td>
<td>11, min</td>
<td>protective oil-type compound</td>
<td>see 5.5</td>
<td>24&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Grade 0D</td>
<td>11, min</td>
<td>protective oil-type compound</td>
<td>see 5.5</td>
<td>72&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Grade I</td>
<td>26–32</td>
<td>protective oil-type compound</td>
<td>see 5.5</td>
<td>168&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Grade II</td>
<td>13–16</td>
<td>zinc-rich&lt;sup&gt;b&lt;/sup&gt; resin flake</td>
<td>15–25</td>
<td>240&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Grade III</td>
<td>13–16</td>
<td>zinc-rich resin powder&lt;sup&gt;c&lt;/sup&gt;</td>
<td>10–20</td>
<td>400&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> When testing Grade 0A finished parts, a protective oil coating shall be added before salt spray testing.
<sup>b</sup> Zinc-rich resin to contain 60 % minimum metallic zinc flake by volume with 14 to 16 % aluminum.
<sup>c</sup> Zinc-rich resin to contain 80 % minimum metallic zinc powder by volume with trace aluminum.

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<sup>1</sup>This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.03 on Metal Coatings on Threaded Fasteners.


<sup>2</sup> Annual Book of ASTM Standards, Vol 03.02.
<sup>3</sup> Annual Book of ASTM Standards, Vol 06.01.
<sup>4</sup> Annual Book of ASTM Standards, Vol 01.08.
where control of the coating cannot be obtained under normal processing such as holes, recesses, threads, etc., the above requirements do not apply.

5.4 Coating Flexibility—These coatings shall withstand the normal flexing encountered by spring clips, or swaged and flared fasteners, without evidence of flaking or loss of adhesion to base metal. They shall also withstand normal handling and storage conditions.

5.5 Thread Fit—The maximum thickness of coating which may be applied to threads on threaded products is limited by the basic thread size (see 8.2). Threads may be produced undersize/oversize (before coating) to accommodate the coating thickness, providing the finished product (after coating) meets all specified mechanical properties. All undersize/oversize must be within permissible limits as agreed upon between the supplier and the purchaser.

5.6 Dry-to-Touch—Grade 0C shall be evenly coated and dry-to-touch such that when held with filter paper or equivalent and applying hand pressure for 5 to 10 s, there shall be no visible staining of the filter paper when viewed without use of supplementary magnification. For referee purposes, this test shall be performed using a force of 10 N as measured with a load-indicating gage.

6. Sampling

6.1 The purchaser may request samples in accordance with Guide F 1470.

7. Test Methods

7.1 The humidity test and adhesion test shall be conducted in accordance with Practice D 2247 and Test Methods D 3359, respectively, for Grades II and III.

7.2 The corrosion resistance shall be determined in accordance with Practice B 117.

7.3 The coating thickness may be determined by microscopic examination of the cross-section taken perpendicular to the significant surface or by determining the coating mass (g/m²) by a weigh-strip-weigh method and then converting to a coating thickness (see note). Coating thickness, for referee purposes, shall be measured by microscopic examination.

**NOTE 1**—The weigh-strip-weigh method involves weighing the test specimen before and after stripping the deposit with a reagent which does not attack the base metal.

The formula used for measuring the thickness of a deposit by the weigh-strip-weigh method is:

\[ T = \frac{W}{A \times D} \times 10^3 \]

where:

- \( T \) = thickness, µm,
- \( W \) = mass of deposit, g,
- \( A \) = area of deposit, m²,
- \( D \) = density of coating, kg/m³.

7.4 The presence of clear topcoat for Grade II may be determined by the sulfamic acid drop test: One to two drops of 1% sulfamic acid shall be dropped on the surface. In the absence of topcoat, the surface will turn black.

8. Inspection

8.1 Samples shall be taken in accordance with Guide F 1470.

8.2 Referee Inspection—The following referee thread inspection procedure may be utilized if the specified “go” gage binds on the screw.

8.2.1 Bolt or Screw—Assemble a phosphate-plated test nut with a 2B or 6H class thread down the full length of the thread.

8.2.2 Nut—Assemble a phosphate-plated test bolt or screw with a 2A or 6g class thread for a minimum of one diameter through the nut.

8.2.3 The test nut or screw/bolt must run freely for the total length without binding.

9. Rejection and Rehearing

9.1 Unless otherwise specified, any rejection based on tests specified herein and made by the purchaser shall be reported to the manufacturer as soon as practical after receipt of the product by the purchaser.
Standard Specification for Aluminum Particle-Filled Basecoat/Organic or Inorganic Topcoat, Corrosion Protective Coatings for Fasteners

This standard is issued under the fixed designation F 1428; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the basic requirements for a corrosion-resistant coating consisting of an inorganic aluminum particle-filled basecoat and an organic or inorganic topcoat, depending on the specific requirements.

1.2 The coating may be specified with basecoat only, or with the top coated with compatible organic polymer or inorganic topcoats, depending on the specific requirements.

1.3 The basecoat is a water-dilutable slurry containing aluminum particles dispersed in a liquid binder of chromate/phosphate compounds.

1.4 The organic topcoats consist of polymer resins and dispersed pigments and are for service where temperatures do not exceed 230°C (450°F).

1.5 The inorganic topcoats consist of ceramic oxide pigments dispersed in a liquid binder of chromate/phosphate compounds and are for service where temperatures do not exceed 645°C (1200°F).

1.6 These coatings are applied by conventional dip/spin, dip/drain, or spray methods.

1.7 The coating process does not normally induce hydrogen embrittlement, provided that the parts to be coated have not been subjected to an acid cleaner or pretreatment (see Note 1).

Note 1—Although this coating material contains water, it has a relatively low susceptibility to inducing hydrogen embrittlement in steel parts of tensile strengths equal to or greater than 1000 MPa (approximately RC31). Normal precautions for preparing, descaling, and cleaning steels of these tensile strengths must be observed. An initial stress relief treatment should be considered prior to any chemical treatment or cleaning operation. Acids or other treatments that evolve hydrogen should be avoided. Mechanical cleaning methods may be considered. Some steels are more susceptible to hydrogen embrittlement than others and may also require hydrogen embrittlement relief baking after cleaning but before coating. Since no process can completely guarantee freedom from embrittlement, careful consideration must be given to the entire coating process and the specific steel alloy employed.

1.8 The coating systems defined by this specification can be applied to ferrous alloy steels, aluminum, and ferritic and austenitic stainless steels.

1.9 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.10 The following safety hazards caveat pertains only to the test methods portion, Section 6, of this specification: This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
  B 117 Test Method of Salt Spray (Fog) Testing
  B 487 Test Method for Measurement of Metal and Oxide Coating Thicknesses by Microscopical Examination of a Cross Section
  B 568 Test Method for Measurement of Coating Thickness by X-Ray Spectrometry
  D 1186 Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base
  D 2247 Practice for Testing Water Resistance of Coatings in 100 % Relative Humidity
  D 3359 Test Methods for Measuring Adhesion by Tape Test
  E 122 Practice for Choice of Sample Size to Estimate a Measure of Quality for a Lot or Process
  E 376 Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Test Methods

3. Classification

3.1 The inorganic aluminum particle-filled basecoat and the subsequent topcoats are classified into three groups, with subsequent subgroups formed according to the requirements given in Table 1. The coating bath requirements and cure temperatures recommended by the chemical manufacturer should be followed.

3.2 Regardless of the processes or materials used, the
TABLE 1 Classification of Coatings

<table>
<thead>
<tr>
<th>Grade No.</th>
<th>Coats of Basecoat</th>
<th>Coats of Topcoats</th>
<th>Average Thickness, µm</th>
<th>Salt Spray Life Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>1</td>
<td>1</td>
<td>10–15</td>
<td>168</td>
</tr>
<tr>
<td>2A</td>
<td>2</td>
<td>1</td>
<td>15–25</td>
<td>240</td>
</tr>
<tr>
<td>3A</td>
<td>2</td>
<td>2</td>
<td>20–30</td>
<td>720</td>
</tr>
<tr>
<td>4A</td>
<td>2</td>
<td>2</td>
<td>20–30</td>
<td>1000</td>
</tr>
<tr>
<td>1B</td>
<td>1</td>
<td>1</td>
<td>10–15</td>
<td>168</td>
</tr>
<tr>
<td>2B</td>
<td>2</td>
<td>1</td>
<td>15–25</td>
<td>240</td>
</tr>
<tr>
<td>3B</td>
<td>2</td>
<td>2</td>
<td>20–30</td>
<td>500</td>
</tr>
<tr>
<td>4B</td>
<td>2</td>
<td>2</td>
<td>20–30</td>
<td>1000</td>
</tr>
<tr>
<td>1C</td>
<td>2</td>
<td>0</td>
<td>10–20</td>
<td>168</td>
</tr>
<tr>
<td>2C</td>
<td>2</td>
<td>0</td>
<td>10–20</td>
<td>400</td>
</tr>
</tbody>
</table>

a Grades with Suffix A are organic topcoated for a maximum service temperature of 230°C (450°F).
b Grades with Suffix B are inorganic topcoated for a maximum service temperature of 645°C (1200°F).
c Grades with Suffix C are basecoated only for a maximum service temperature of 645°C (1200°F).

4. Ordering Information

4.1 Orders for material in accordance with this specification shall include the following information:

4.1.1 Quantity of parts,
4.1.2 Grade of coating (see Table 1),
4.1.3 Color of coating,
4.1.4 Any additions to specifications as agreed upon by the purchaser and the supplier, and
4.1.5 Certification and test report requirements.

5. Requirements

5.1 Appearance—The coatings shall have a smooth, uniform appearance and shall be free of lacerations and other discontinuities that may affect the appearance or performance of the coatings. All topcoat colors shall be agreed upon by both the purchaser and the supplier.

5.2 Adhesion—The coating shall show no evidence of blistering or other appearance changes after exposure to humidity testing for 96 h, it shall show no more than 3.0-mm peel-back from the intersection of scribed lines that are tape-tested immediately after a 10-min recovery period from the humidity test, and there shall be no other peeling under the tape.

5.3 Corrosion—These coatings shall be capable of withstanding neutral salt spray testing for the minimum time specified in Table 1. Unless otherwise defined, acceptable corrosion resistance shall be considered to be met where there is no base metal corrosion on significant surfaces.

5.3.1 Significant surfaces on threaded fasteners are defined as the surfaces exposed when the fasteners are installed in a normal manner (bolt head, nut drive, face, etc.). On other surfaces on which coating control cannot be obtained under normal processing, such as holes, recesses, threads, etc., the above requirements do not apply.

5.4 Thread-Fit—The coating shall not have an adverse effect on normal installation and removal practices, as determined by the proper “GO” thread gage or the fit and function inspection method (see 8.2).

5.4.1 Sizing—The thickness of the coating is limited by the basic thread size. Where greater thickness is necessary, threads may be produced undersize or oversize (before coating) to accommodate the coating thickness, providing that the finished fastener (after coating) meets all specified mechanical properties, as agreed upon by the supplier and the purchaser.

5.5 Weathering—The coatings shall show no blistering, peeling, cracking, loss of adhesion, discoloration, or red rust on significant surfaces after exposure to the weathering test for at least as many hours as specified for salt spray resistance for the various codes.

6. Test Methods

6.1 Corrosion—Corrosion resistance shall be tested in accordance with Test Method B 117.

6.2 Coating Thickness—Coating thickness shall be tested in accordance with Test Methods D 1186, magnetic-permeability; Practice E 376, eddy-current; or Test Method B 568, X-ray spectrometry. For referee purposes, micro-examination in accordance with Test Method B 487 shall be used.

6.3 Humidity Test—The humidity test shall be conducted in accordance with Practice D 2247.

6.4 Adhesion—After exposure to the humidity test, adhesion shall be tested in accordance with Test Methods D 3359.

7. Application

7.1 Any conventional cleaning procedure that does not induce hydrogen embrittlement or intergranular attack of the basis metal can be used, followed by grit blasting or micro-zinc phosphating (see Note 2).

Note 2—If not properly controlled, zinc phosphate coatings and certain acid descaling processes may produce hydrogen embrittlement or severe etching of the basis metal.

7.2 The coatings are applied by conventional dip/spin, dip/drain, or spray methods.

7.3 The coatings shall be applied under suitable control conditions and in the stages necessary to meet the requirements of the specification. Unless otherwise specified, these coatings shall be applied after all machining, forming, and heat treatments have been completed, but prior to final inspection.

7.4 The contractor (applicator) shall maintain control over factors that affect the quality of the treatment, including, but not limited to, dip/spin parameters, coating viscosities, and temperature. Chemical analyses, coating replenishment, visual inspection, and other process control devices shall be conducted with the frequency required to maintain good quality of the treatment and to meet the requirements of this specification. Visual inspection is intended to include appearance factors such as (1) streaking, (2) dulling, (3) uncoated areas, and (4) loss of color where color is specified.

8. Inspection

8.1 Samples may be taken in accordance with Practice
E 122 or as agreed upon by the purchaser and the supplier.

8.1.1 A lot shall consist of all items having the same coating specification and processed at the same time.

8.2 **Fit and Function Inspection**—The following fit and function thread inspection procedure may be used if the specified “GO” gage binds on the threads.

8.2.1 **Bolt or Screw**—Assemble a phosphate-plated test nut with a 2B or 6H class thread fit down the full length of the thread.

8.2.2 **Nut**—Assemble a phosphate-plated test screw with a 2A or 6g class thread for a minimum of one diameter through the nut.

8.2.3 The test nut or screw must run freely for the total length without binding.

9. **Rejection and Rehearing**

9.1 Unless otherwise specified, any rejection based on the tests specified herein and made by the purchaser shall be reported to the manufacturer as soon as practical after receipt of the fasteners by the purchaser.

10. **Certification Requirement**

10.1 Product designations used in the coating system are to be reported to the purchasing organization, along with certification that the parts meet the requirements of this specification.

10.2 When applicable, test reports affirming acceptance are to be attached to the certification.

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Standard Guide for Conducting a Repeatability and Reproducibility Study on Test Equipment for Nondestructive Testing

This standard is issued under the fixed designation F 1469; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope
1.1 This guide describes the steps required to conduct a complete repeatability and reproducibility (RR) study on nondestructive test equipment. This guide is a manual (use of calculator) method. Other methods may utilize the application of computer driven software.
1.2 This guide can be used to evaluate all test equipment that provides variable measuring data.

2. Terminology
2.1 Definitions:
2.1.1 repeatability—the variation in the values of measurements obtained when one operator uses the same gage for measuring identical characteristics of the same parts.
2.1.2 reproducibility—the variation in the average of measurements made by different operators using the same parts.

3. Significance and Use
3.1 This guide is recommended for the purpose of evaluating test equipment that may be utilized in statistical process control, testing laboratories, and for in-process control of manufacturing operations.
3.2 Ask the question: What effect does the operator have on the measurement process? If possible, the operators who normally use the test equipment should be included in the study. If operator calibration of the equipment is likely to be a significant cause of variation, then the operator should recalibrate the equipment prior to each group of readings.
3.3 The test equipment should provide direct readings in which the smallest digit is no larger than one tenth of the tolerance of the characteristic being evaluated.
3.4 It is recommended that a test equipment repeatability and reproducibility study be a mandatory part of all test equipment purchases and that acceptance criteria be <10 % for certification and statistical process control (SPC) use.

4. Equipment Certification
4.1 Test equipment shall be certified through use of certified standards as accurate to the manufacturer’s / user’s calibration systems with certified standards before a repeatability and reproducibility study is performed.
4.2 Certifications must be traceable to the National Institute of Standards and Technology (NIST), or recognized equivalent, and shall be current to the test equipment’s calibration schedule.

5. Procedure
5.1 Although the number of operators, trials, and parts may be varied, the following guidelines represent the optimum conditions for conducting a study using the forms in Figs. 1 and 2.
5.2 Select three operators and identify them as Operators A, B, and C.
5.3 Calibrate the test equipment with a certified standard.
5.4 Select ten parts for measurements and number them from 1 to 10, such that the numbers, if possible, are not visible to the operator. Place a mark on each part to indicate the precise position at which the part shall be measured. This eliminates the variation within the part from the study results so that only the gage’s performance and operator variation influences the study outcome.
5.5 Allow Operator A to inspect all ten parts in a sequential order by measuring each part at the designated location. Enter the results in the 1st trial column for Operator A of the Repeatability and Reproducibility Data Sheet (Fig. 1). Part identification and associated data entry shall be performed by an observer.
5.6 Repeat 5.5 with Operators B and C and enter the results in the corresponding 1st trial column for each operator.
5.7 Repeat 5.5 and 5.6 using a random selection of the ten parts. Enter data in the 2nd trial column for each operator. If three trials are needed, repeat the cycle and enter data in the corresponding 3rd trial column for each operator.
5.8 Steps 5.5, 5.6, and 5.7 may be changed to the following when large part size or simultaneous availability of parts is not possible:
5.8.1 Allow Operators A, B, and C to measure the first part and record their readings in the corresponding 1st trial columns for each operator.
5.8.2 Allow Operators A, B, and C to remeasure the first part and record their readings in the corresponding 2nd trial columns for each operator. If three trials are to be used, repeat the cycle and enter the results in the corresponding 3rd trial columns for each operator.
5.9 If the operators are not available at the same time, the following method may be used. Allow Operator A to measure all ten parts at once and enter the results in the 1st trial column for Operator A. Repeat the measurements in a different order and enter the results in the corresponding 2nd and 3rd trial columns for Operator A. Do the same with Operators B and C, as soon as they are available entering their data in their corresponding 1st, 2nd, and 3rd trial columns.

5.10 Make all necessary calculations on the Repeatability and Reproducibility Data Sheet (Fig. 1) and Repeatability and Reproducibility Report (Fig. 3). For clarity, Fig. 4 and Fig. 2 are provided as examples.

6. Analysis of Results

6.1 Evaluate the data following the steps on the data sheets to determine if the test equipment is acceptable for its intended application. The criteria for acceptability is dependent upon the percentage of part tolerance that is consumed by the test equipment error. Acceptability is based upon the following criteria:

6.1.1 Test equipment with a repeatability and reproducibility percentage of 10% or less is fully capable and may be used for certification testing.

6.1.2 Test equipment with a repeatability and reproducibility percentage between 10 and 30% shall be reviewed by a qualified technician. If possible, the testing system should be improved or replaced; however, the system may continue to be used as is until an improvement is found.

6.1.3 Test equipment with a repeatability and reproducibility percentage greater than 30% is unacceptable. Take immediate corrective action to replace or improve the testing system.

7. Keywords

7.1 repeatability; reproducibility; statistical process control; test equipment
FIG. 2 Gage Repeatability and Reproducibility Data Sheet

### Measurement Unit Analysis

**Repeatability - Equipment Variation (E.V.)**

\[
E.V. = \frac{R}{K - 1} \times (K - 1)
\]

\[
= \frac{0.113333}{4.56} \times 4.56
\]

<table>
<thead>
<tr>
<th>Trials #</th>
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<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>0.5168</td>
<td></td>
</tr>
<tr>
<td>K-1</td>
<td>4.56</td>
<td></td>
</tr>
<tr>
<td>Tolerance</td>
<td>3.05</td>
<td></td>
</tr>
</tbody>
</table>

**Reproducibility - Appraiser Variation (A.V.)**

\[
A.V. = \frac{d(0.495) + (K - 2)(R \cdot V^2) / (n + n)}{d(0.495) + (K - 2)(R \cdot V^2) / (n + n)}
\]

\[
= \frac{0.228994}{2.7}
\]

<table>
<thead>
<tr>
<th>Operator #</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>3.65</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>2.7</td>
<td></td>
</tr>
</tbody>
</table>

\(n = \# \text{ parts} \quad r = \# \text{ trials}\)

**Repeatability and Reproducibility (R & R)**

\[
= \sqrt{(E.V.)^2 + (A.V.)^2}
\]

\[
= \sqrt{(0.5168)^2 + (0.228994)^2}
\]

\[
= 0.565261
\]

* Guidelines for acceptance are referenced in "Measurement System Analysis" by A.I.Q.O., 1990, page 46. All calculations are based upon predicting 3.15 sigma (99.9% of the area under the normal distribution curve). A.V. = if a negative value is calculated under the square root sign, the appraiser variation (A.V.) defaults to zero (0).

### % Tolerance Analysis

**% E.V. =**

\[
= 100 \left( \frac{E.V.}{\text{Tol}} \right)
\]

\[
= 100 \left( \frac{0.5168}{5} \right)
\]

\[
= 10.34
\]

**% A.V. =**

\[
= 100 \left( \frac{A.V.}{\text{Tol}} \right)
\]

\[
= 100 \left( \frac{0.228994}{5} \right)
\]

\[
= 4.58
\]

**% R&R =**

\[
= \sqrt{(E.V.)^2 + (A.V.)^2}
\]

\[
= \sqrt{(0.5168)^2 + (0.228994)^2}
\]

\[
= 11.3\%
\]

* Guidelines for acceptance are:
  - Under 10% error - gage system O.K.
  - 10% - 30% error - may be acceptable based on importance of application, cost of gage, cost of repairs, etc.
  - Over 30% error - gage system needs improvement. Make every effort to identify the problems and have them corrected.
FIG. 3 Gage Repeatability and Reproducibility Data Sheet

### Sample #

<table>
<thead>
<tr>
<th>Operator A</th>
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<th>Operator C</th>
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<td>35.8</td>
</tr>
<tr>
<td>3</td>
<td>36.1</td>
<td>35.9</td>
</tr>
<tr>
<td>4</td>
<td>36.3</td>
<td>35.8</td>
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<td>36.2</td>
</tr>
<tr>
<td>10</td>
<td>35.9</td>
<td>36.0</td>
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### 1st Trial

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<th>Operator C</th>
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<td>35.9</td>
<td>35.7</td>
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<td>35.8</td>
</tr>
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<td>35.7</td>
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### 3rd Trial

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<td>0</td>
</tr>
</tbody>
</table>

### Range

<table>
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<th>Operator B</th>
<th>Operator C</th>
</tr>
</thead>
<tbody>
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<td>0.1</td>
<td>0.1</td>
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<tr>
<td>0.2</td>
<td>0.2</td>
<td>0.3</td>
</tr>
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<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### Part A

- \( \bar{X} \_A = 35.925 \)
- \( \sum A = 718.5 \)
- \( \bar{X} \_A = 35.925 \)

### Part B

- \( \bar{X} \_B = 35.995 \)
- \( \sum B = 719.9 \)

### Part C

- \( \bar{X} \_C = 35.9 \)
- \( \sum C = 718 \)

### Range

- \( R \_A = 0.09 \)
- \( R \_B = 0.11 \)
- \( R \_C = 0.14 \)

### D4 and D3 Constants

- \( D_4 = 3.27 \)  
- \( D_3 = 1.86 \)

### Notes

Reference: The D4 Constant is obtained from the table of Factors for X-Bar, R charts, page 12, Western Electric Statistical Quality Control Handbook.

FIG. 3 Gage Repeatability and Reproducibility Data Sheet
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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

FIG. 4 Gage Repeatability and Reproducibility Data Sheet

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Standard Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

This standard is issued under the fixed designation F 1470; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

Throughout this guide the terms detection and prevention apply to quality control systems. A brief description of both is provided to assist the purchaser in the application of this guide.

The detection system relies on inspection as the primary means of controlling the quality of furnished material. Methods include in-process and final inspection. In-process inspection is typically performed by the individual performing the process and generally includes a first-piece inspection by someone other than the operator. Quality-control inspection may perform audit inspections on the process output during the course of the production run. In addition, a final inspection is performed by quality control inspectors according to a prescribed sample plan. The other sample plans utilize zero defects as their acceptance criteria.

The prevention system uses advanced quality planning in addition to many of the techniques used in the detection system. Quality planning incorporates a systems approach to quality control that focuses on defect prevention and continual improvement. In addition, Statistical Process Control (SPC) is usually applied to control the process, thereby reducing the variability of the output.

The ISO 9000, QS 9000, and the ASQ Q9000, quality system standards, or a combination thereof, are models that may be used in establishing a prevention-based quality system.

1. Scope

1.1 This guide provides sampling methods for determining how many fasteners to include in a random sample in order to determine the acceptability or disposition of a given lot of fasteners.

1.2 This guide is for mechanical properties, physical properties, coating requirements, and other quality requirements specified in the standards of ASTM Committee F16. Dimensional and thread criteria sampling plans are the responsibility of ASME Committee B18.

1.3 This guide provides for two sampling plans: one designated the “detection process,” as described in Terminology F 1789, and one designated the “prevention process,” as described in Terminology F 1789.

2. Referenced Documents

2.1 ASTM Standards:
F 1789 Terminology for F16 Mechanical Fasteners

2.2 ASME Standards:
ASME B18.18.2M Inspection and Quality Assurance for High-Volume Machine Assembly Fasteners
ASME B18.18.3M Inspection and Quality Assurance for Special Purpose Fasteners
ASME B18.18.5M Inspection and Quality Assurance Plan Requiring In-Process Inspection and Controls
ASME B18.18.6M Quality Assurance Plan for Fasteners Produced in Third Party Accreditation System

2.3 ASQ Standards:
ASQ Q9000 Quality Management and Quality Assurance Standards—Guidelines for Selection and Use
ASQ Q9001 Quality Management Systems
ASQ Q9002 Quality Systems—Model for Quality Assurance in Production and Installation
ASQ Q9004 Quality Management and Quality System Elements—Guidelines for Quality Improvement

2.4 AIAG Standards:
QS 9000 Quality System Requirements

2.5 ISO Standards:

---

1 Available from the American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.
3. Terminology

3.1 Terms shall be defined in accordance with Terminology F 1789.

3.2 Definitions:

3.2.1 material review, $n$—an evaluation by a team of fastener experts to determine the fastener’s nonconformance with respect to fitness for general use, fitness for intended use, or fitness for specified use.

3.2.2 random sampling, $n$—when every fastener in the lot has an equal and independent chance of being chosen as the sample. The sample may be returned to the lot if it has not been altered or destroyed during the inspection/test upon completion of sampling.

3.2.3 test, $n$—an element of inspection that generally denotes the determination by technical means of the properties or elements of supplies, or components thereof and involves the application of established scientific principles and procedures.

3.2.4 zero defects, $n$—zero defects applies only to the random sample. It gives a 95% confidence level that the shipping lot is free from defects.

4. Significance and Use

4.1 Sampling shall be selected in a random manner, ensuring that any unit in the lot has an equal chance of being chosen. Sampling should not be localized by selections being taken from the top of a container or from only one container of multicontainer lots.

4.2 The purchaser should be aware of the supplier’s quality assurance system. This can be accomplished by auditing the supplier’s quality system, if qualified auditors are available, or by third-party assessment certification, such as provided by QS 9000, ASQ 9000, or ISO 9000.

5. Ordering Information

5.1 The purchaser shall specify at the time of order inquiry, the specification number, the issue date and the sampling plan (detection process or prevention process) required from the supplier.

5.2 Guidelines for sampling plan selection are provided in Section 6.

6. Selection of Sampling Plans

6.1 Except as specified in 6.2, the detection process sampling level in accordance with Table 1 shall be applied.

6.2 If the manufacturer’s quality system conforms with ASME B18.18.5M, B18.18.6M, QS 9000, ASQ Q9001, Q9002 (up until the year 2003), ISO 9001, or ISO 9002 (up until the year 2003), the manufacturer shall be permitted to choose between the Prevention or Detection process for inspection and test purposes. Purchasers shall retain the right to specify the Prevention or Detection process at the time of inquiry or order (see Table 2).

7. Acceptance Criteria

7.1 The acceptance criteria for Table 3 is to accept the lot if zero nonconforming parts are detected in the random sample and reject the lot if at least one nonconforming part is detected in the random sample.

8. Disposition of Nonconforming Lots

8.1 Manufacturer’s Options—The manufacturer shall choose one of the following options in the disposition of those fasteners that have been found to contain nonconformities prior to shipment. The fastener manufacturer shall maintain records of disposition.

8.1.1 They may be scrapped.

8.1.2 They may be 100% sorted, and all nonconforming parts removed.

8.1.3 They may be reworked or reprocessed to correct the nonconforming characteristic(s).

8.1.4 The manufacturer may make concession by use of a documented internal review procedure and determine to ship product that is found to contain minor nonconformances that are not critical or key characteristics as determined by the end user. Nonconformance of critical or key characteristics shall need approval from the end user prior to shipment of product. (See 8.1.6.) (See QS 9000, 4.13.1.2, b.)

8.1.5 They may be regraded for alternative applications. (See QS 9000, 4.13.1.2, c.)

8.1.6 The end user may be informed of the nonconformity or nonconformities and his advice requested on their disposition. The user may consider the degree to which the characteristic(s) deviate(s) from specified requirements and the significance of the effect on the assembly or performance of the fasteners in their service application. The user may authorize a written release of the fasteners for completion of production or for shipment, as applicable.

8.2 End User Options—The end user shall choose one of the following options for the disposition of those fastener lots that have been rejected after delivery:

8.2.1 The end user considers the degree to which the characteristic(s) deviate(s) from specified requirements and the effect on their performance in the intended service application. The end user may authorize release of the parts or fastener lots for use.

8.2.2 They may be scrapped.

8.2.3 They may be 100% sorted and nonconforming parts removed.

8.2.4 They may be reworked or reprocessed to correct the nonconforming characteristic(s).

8.2.5 They may be returned.
TABLE 1  Sampling Level for the Detection Process

NOTE 1—Legend: WA—Where Applicable. NA—Not Applicable.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Sample Level&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Internally Threaded Parts</th>
<th>Externally Threaded Parts</th>
<th>Non-threaded</th>
<th>Washers</th>
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</thead>
<tbody>
<tr>
<td>Adhesion (coating)</td>
<td>C</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
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<tr>
<td>Assembly tension test</td>
<td>B</td>
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<td>NA</td>
<td>NA</td>
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<tr>
<td>Bend, body (nails)</td>
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<td>NA</td>
<td>NA</td>
<td>WA</td>
<td>NA</td>
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<td>B</td>
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<td>WA</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>Bend, body (track spikes)</td>
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<td>NA</td>
<td>NA</td>
<td>WA</td>
<td>NA</td>
</tr>
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<td>WA</td>
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<td>WA</td>
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<td>Grain size&lt;sup&gt;c&lt;/sup&gt;</td>
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<td>Impact</td>
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<td>Packaging&lt;sup&gt;e&lt;/sup&gt;</td>
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<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
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<td>Plating/coating thickness ( weight)</td>
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<td>WA</td>
<td>WA</td>
<td>WA</td>
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<tr>
<td>Product identification marking&lt;sup&gt;f&lt;/sup&gt;</td>
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<tr>
<td>Proof load—Full size</td>
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<td>NA</td>
<td>NA</td>
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<td>Reduction of area—Machined specimen</td>
<td>C</td>
<td>NA</td>
<td>WA</td>
<td>WA</td>
<td>NA</td>
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<td>Bend, rivet</td>
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<td>NA</td>
<td>NA</td>
<td>WA</td>
<td>NA</td>
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<tr>
<td>Flattening, rivet</td>
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<td>NA</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>Rotational capacity</td>
<td>C</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>NA</td>
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<tr>
<td>Salt spray&lt;sup&gt;g&lt;/sup&gt;</td>
<td>B</td>
<td>WA</td>
<td>WA</td>
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<td>WA</td>
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<td>Shear strength</td>
<td>C</td>
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<td>WA</td>
<td>WA</td>
<td>NA</td>
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<tr>
<td>Stress corrosion</td>
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<td>WA</td>
<td>WA</td>
<td>WA</td>
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<td>Surface discontinuities</td>
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<td>WA</td>
<td>WA</td>
<td>WA</td>
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<tr>
<td>Surface roughness</td>
<td>B</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Tensile strength—Full size</td>
<td>C</td>
<td>NA</td>
<td>WA</td>
<td>WA</td>
<td>NA</td>
</tr>
<tr>
<td>Tensile strength—Machined specimen</td>
<td>C</td>
<td>NA</td>
<td>WA</td>
<td>WA</td>
<td>NA</td>
</tr>
<tr>
<td>Torque&lt;sup&gt;h&lt;/sup&gt; ( prevailing)</td>
<td>C</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>NA</td>
</tr>
<tr>
<td>Torque (torsional strength)</td>
<td>C</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>NA</td>
</tr>
<tr>
<td>Yield strength—Full size</td>
<td>C</td>
<td>NA</td>
<td>WA</td>
<td>WA</td>
<td>NA</td>
</tr>
<tr>
<td>Yield strength—Machined specimen</td>
<td>C</td>
<td>NA</td>
<td>WA</td>
<td>WA</td>
<td>NA</td>
</tr>
</tbody>
</table>

<sup>a</sup> Quantity of samples is in Table 3, Sample Size.

<sup>b</sup> A certified copy of the material’s chemical or product analysis shall be furnished with each shipping lot, and the shipping lot shall have documentation providing traceability to this chemical analysis. It is required that the purchaser of the raw material (used to manufacture) shall verify that the material is the material specified on the purchase order.

<sup>c</sup> The steel producer shall provide the steel making practice (course or fine grain) on their certification. The steel producer may specify grain size at their option.

<sup>d</sup> Surface or core, or both, as applicable.

<sup>e</sup> All packaging requirements shall be in conformance with the applicable packaging standard.

<sup>f</sup> Visual inspection for conformance.

<sup>g</sup> Continuous monitoring of salt spray performance in accordance with the recommendation of Table B in Appendix 1 of ASME B18.18.2M constitutes compliance with the requirements for salt spray testing outlined in this table.

<sup>h</sup> Wedge angle or axial test as applicable.

<sup>i</sup> Prevailing torque test includes thread start, all specified torque requirements, and retention of locking feature, when applicable.
### TABLE 2 Sampling Level for the Prevention Process

**NOTE 1**—Legend: WA—Where Applicable. NA—Not Applicable.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Sample Level</th>
<th>Internally Threaded Parts</th>
<th>Externally Threaded Parts</th>
<th>Non-threaded</th>
<th>Washers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adhesion (coating)</td>
<td>D</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Assembly tension test</td>
<td>C</td>
<td>NA</td>
<td>WA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Bend, body (nails)</td>
<td>B</td>
<td>NA</td>
<td>NA</td>
<td>WA</td>
<td>NA</td>
</tr>
<tr>
<td>Bend, notched (bolts)</td>
<td>C</td>
<td>NA</td>
<td>WA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Bend, body (track spikes)</td>
<td>D</td>
<td>NA</td>
<td>NA</td>
<td>WA</td>
<td>NA</td>
</tr>
<tr>
<td>Breaking strength (eyebolts)</td>
<td>D</td>
<td>NA</td>
<td>WA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Carbide precipitation</td>
<td>D</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Case depth/decarburization</td>
<td>D</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Chemistry</td>
<td>—</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Compression (washer direct tension)</td>
<td>B</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Cone proof</td>
<td>D</td>
<td>WA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Drive test</td>
<td>B</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Elongation—Machined specimen</td>
<td>D</td>
<td>NA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Extension at failure</td>
<td>D</td>
<td>NA</td>
<td>WA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Grain size</td>
<td>D</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Hardness</td>
<td>D</td>
<td>WA</td>
<td>WA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Bend, head (track spikes)</td>
<td>D</td>
<td>NA</td>
<td>WA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Humidity</td>
<td>C</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Hydrogen embrittlement</td>
<td>C</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Impact</td>
<td>D</td>
<td>NA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Lubrication</td>
<td>C</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Magnetic permeability</td>
<td>C</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Packaging</td>
<td>—</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Plating/coating thickness (weight)</td>
<td>B</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Product identification marking</td>
<td>—</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Proof load—Full size</td>
<td>D</td>
<td>WA</td>
<td>WA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Reduction of area—Machined specimen</td>
<td>D</td>
<td>NA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Bend, rivet</td>
<td>C</td>
<td>NA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Flattening, rivet</td>
<td>C</td>
<td>NA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Rotational capacity</td>
<td>D</td>
<td>WA</td>
<td>WA</td>
<td>NA</td>
<td>WA</td>
</tr>
<tr>
<td>Salt spray</td>
<td>C</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Shear strength</td>
<td>D</td>
<td>NA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Stress corrosion</td>
<td>C</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Surface discontinuities</td>
<td>C</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Surface roughness</td>
<td>C</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
<td>WA</td>
</tr>
<tr>
<td>Tensile strength—Full size</td>
<td>D</td>
<td>NA</td>
<td>WA</td>
<td>WA</td>
<td>NA</td>
</tr>
<tr>
<td>Tensile strength—Machined specimen</td>
<td>D</td>
<td>NA</td>
<td>WA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Torque (prevailing)</td>
<td>D</td>
<td>WA</td>
<td>WA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Torque (torsional strength)</td>
<td>D</td>
<td>WA</td>
<td>WA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Yield strength—Full size</td>
<td>D</td>
<td>NA</td>
<td>WA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Yield strength—Machined specimen</td>
<td>D</td>
<td>NA</td>
<td>WA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

A Final inspection of a characteristic may be carried out at any stage of manufacture, provided the characteristic is not subject to change in any further manufacturing or processing operation. Therefore, the testing of those samples may be deducted from the sample level specified.

B Quantity of samples is in Table 3, Sample Size.

C A certified copy of the material’s chemical or product analysis shall be furnished with each shipping lot, and the shipping lot shall have documentation providing traceability to this chemical analysis. It is required that the purchaser of the raw material (used to manufacture) shall verify that the material is the material specified on the purchase order.

D Steel making practice (course or fine grain) shall be included with the material producer’s chemical analysis report.

E Surface, core, or both, as applicable.

F All packaging requirements shall be in conformance with the applicable packaging standard.

G Visual inspection for conformance.

H Continuous monitoring of salt spray performance in accordance with the recommendation of Table B in Appendix 1 of ASME B18.18.2M constitutes compliance with the requirements for salt spray testing outlined in this table.

I Wedge angle or axial test as applicable.

J Prevailing torque test includes thread start, all specified torque requirements, and retention of locking feature, when applicable.
8.3 Distributor Options—The distributor shall choose one of the following options for the disposition of those fastener lots that have been rejected after delivery.

8.3.1 They may be scrapped.

8.3.2 They may be 100% sorted, and nonconforming parts may be removed with the written agreement of the manufacturer.5

8.3.3 They may be reworked or reprocessed to correct the nonconforming characteristic(s) with the written agreement of the manufacturer.5

8.3.4 They may be returned.5

8.4 Reinspection—All fastener lots that have been sorted, reworked, or reprocessed, or a combination thereof, under the jurisdiction of the manufacturer or distributor shall be reinspected for the characteristic(s) found nonconforming and all other characteristics that would be affected by the reworking or reprocessing operation(s). If no parts inspected are found nonconforming, the fastener lots may be approved for delivery or use, as applicable. Reinspection shall be performed using the same or a more stringent sample plan that was used in detecting the original nonconformance. The acceptance level shall be in accordance with 7.1.

9. Control of Measuring and Test Equipment

9.1 Control should be maintained over all measuring and test equipment to provide confidence in decisions or actions based on measurement or test data. As a minimum, these controls shall follow the guidelines provided in ISO 9004, or ASQ Q9004, on the portion that details the control of measuring and test equipment.

10. Keywords

10.1 detection systems; fasteners; inspection for mechanical properties; performance requirements; prevention systems; quality requirements; sampling plans; selection and size; statistical process control

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5 In general, product standards specify requirements for manufacturers’ markings. Lot control, invoice information, and packaging may be another source of identification of the manufacturer.

---

TABLE 3 Sample Size

<table>
<thead>
<tr>
<th>Lot Size</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>1 to 2</td>
<td>2</td>
</tr>
<tr>
<td>3 to 15</td>
<td>3</td>
</tr>
<tr>
<td>16 to 25</td>
<td>4</td>
</tr>
<tr>
<td>26 to 50</td>
<td>5</td>
</tr>
<tr>
<td>51 to 90</td>
<td>6</td>
</tr>
<tr>
<td>91 to 150</td>
<td>7</td>
</tr>
<tr>
<td>151 to 280</td>
<td>10</td>
</tr>
<tr>
<td>281 to 500</td>
<td>11</td>
</tr>
<tr>
<td>501 to 1200</td>
<td>15</td>
</tr>
<tr>
<td>1201 to 3200</td>
<td>18</td>
</tr>
<tr>
<td>3201 to 10 000</td>
<td>22</td>
</tr>
<tr>
<td>10 001 to 35 000</td>
<td>29</td>
</tr>
<tr>
<td>35 001 to 150 000</td>
<td>29</td>
</tr>
<tr>
<td>150 001 to 500 000</td>
<td>29</td>
</tr>
<tr>
<td>500 001 and over</td>
<td>29</td>
</tr>
</tbody>
</table>

A Suppliers shall furnish certified test results from which the shipping lots originated. If certified test reports are not available, then the supplier must default to Sample Size C and conduct the tests required.
Standard Practice for Machine/Process Capability Study Procedure

This standard is issued under the fixed designation F 1503; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope *

1.1 This practice covers provision of a proper method for determining process capability for new or existing machine processes. It is recommended that available statistical software be used for the calculation of the descriptive statistics required for decision making when using this practice. Where software is not available, Section 8 and Tables 1 and 2 are provided for manual calculations.

2. Referenced Documents

2.1 ASTM Standards:
F 1469 Guide for Conducting a Repeatability and Reproducibility Study on Test Equipment for Nondestructive Testing2

3. Terminology

3.1 Definitions of Terms Specific to This Standard:
3.1.1 bilateral specifications—specifications that have both upper and lower values.
3.1.2 \( C_p \)—an index that indicates the variability of the process with respect to tolerance.
3.1.3 \( C_p k \)—an index of process variability and centering. This is a widely-used index which considers the process mean, range, and its relation to the specification nominal.
3.1.4 inspection plan—a set of instructions defining product characteristics, specifications, frequency of inspection, acceptance criteria, and methods of inspection for product at a specified operation.
3.1.5 process parameters—combination of people, equipment, materials, methods, and environment that produce output.
3.1.6 unilateral specifications—specifications that have only upper or lower values.
3.1.7 \( \sigma \)—an estimate of the standard deviation of a process characteristic.

4. Summary of Practice

4.1 A machine/process capability (MPC) study is conducted to provide a level of confidence in the ability of a machine/process to meet engineering specification requirements. This is accomplished through statistical process control techniques as defined in this practice.

4.2 For new equipment purchases, the purchaser’s manufacturing department, or equivalent discipline, shall have primary responsibility for ensuring that the requirements of this practice are met. The purchaser’s quality assurance department shall be available to assist on an as-requested basis.

4.3 New machines/processes will not be accepted for use in production with \( C_p \) values less than 1.67. If a manufacturing process must be conditionally accepted, a process improvement/product control plan shall be developed.

4.3.1 The machine/process control plan shall identify specific process improvement activities, which will be implemented to make the process more capable as well as an interim inspection plan to ensure that nonconforming product is not shipped to a customer.

4.4 Product Specifications:

4.4.1 Prior to any MPC study, the product specifications (nominal dimension and tolerances) must be identified, and an appropriate method of variables type inspection selected.

4.4.2 This practice is limited to bilateral specifications whose distributions can be expected to approximate a normal curve. This practice should not be applied to unilateral specifications (flatness, concentricity, minimum tensile, maximum hardness, etc.).

4.5 Gage Capability Analysis:

4.5.1 All gaging systems used to evaluate product involved in the study must have documentation for a gage repeatability and reproducibility study in accordance with Guide F 1469 before the machine/capability study is conducted.

4.5.1.1 Gaging systems which consume \( \leq 10 \% \) of the applicable product tolerance are considered acceptable.

4.5.1.2 Gaging systems which consume over 10 to 30 \% of the applicable product tolerance are generally considered to be unacceptable. However, users of this guide may authorize their use depending on factors such as the criticality of the specification in question, the cost of alternative gaging systems, and so forth.

4.5.1.3 Gaging systems which consume more than 30 \% of the product tolerance are unacceptable and must not be used.

4.5.2 All gaging systems must be certified as accurate using
standards traceable to NIST, other recognized standards organizations, or the equivalent manufacturer’s standard.

4.6 Process Parameter Selection:
4.6.1 For studies conducted at the equipment vendor’s facility, all machine/process parameters (for example, infeed rates, coolant, dies, pressures, fixtures, etc.) must be established and documented prior to the MPC study so the requirements of 9.5 can be met.
4.6.1.1 Machine/process parameters may not be changed once an MPC study has begun.
4.6.1.2 All machine/process adjustments made during the MPC study must be documented and included with information required in Section 10.1 of this practice.

4.6.2 The selection of machine/process parameters is the responsibility of the purchaser’s manufacturing engineering or equivalent discipline, or, in some cases, the machine supplier depending on preestablished contractual agreements.
4.6.2.1 The machine/process parameters selected must be consistent with those intended to be used in production.
4.6.3 Machine/process parameters may be systematically varied after a study is completed and additional MPC studies performed for optimization purposes.

5. Significance and Use
5.1 This practice is designed to evaluate a machine or process isolated from its normal operating environment. In its normal operating environment, there would be many sources of variation that may not exist at a machine/process builder’s facility; or put another way, this study is usually conducted under ideal conditions. Therefore, it should be recognized that the results of this practice are usually a “best case” analysis, and allowances need to be made for sources of variations that may exist at the purchaser’s facility.

6. Material Selection
6.1 Material (for example, steel slugs, bar, wire, prefinished parts, etc.) used for MPC studies shall be selected at random. The variability of material used for MPC studies should be consistent with the variability of material the machine is likely to see in production. However, all selected samples shall conform to their applicable product engineering standards.
6.2 Presorting of material is not permissible for machine/process qualification purposes.
6.3 In some cases, machine/process capability results may be influenced by the specific product specifications selected for the study. The specific product selected for qualifying a new machine/process should be based on that which will yield the most conservative results. If the relationship between specific product specifications and machine/process capability is unknown, two or more distinct studies should be performed with different products to qualify and accept the new machine/process.

7. Procedure-Machine/Process Capability Study
7.1 Operate the machine/process for a sufficient period of time to ensure that the machine/process is stable and all initial setup adjustments are complete.
7.2 Control charting techniques should be utilized to determine the stability and capability of the machine/process.
7.2.1 When possible, a standard $\bar{X}$, $R$ chart should be used with subgroup size $n$ equals 2 through 5.
7.2.1.1 Sampling frequencies shall be established to ensure that all likely sources of variability occur.
7.2.1.2 A minimum of 25 subgroups are required to establish control.
7.2.2 When the quantity of sample measurements cannot be practically obtained, it is permissible to utilize a chart for individuals and moving ranges.
7.2.2.1 A minimum of 25 subgroups are required to establish control.
7.2.2.2 After the study is complete, calculate and plot the control limits, $\bar{X}$ and $R$ (or $MR$), for each specification identified in 4.4.1 (see Table 1). If during the study the machine/process was out of control, the MPC study is not valid. The root cause(s) of the out-of-control condition(s) must be identified and eliminated and the study repeated.
7.2.2.3.1 If the out-of-control condition is associated with no more than two subgroups on the range chart, one point on the $\bar{X}$ or individuals chart and the root cause of the out-of-control condition is identified and corrected, new control limits may be calculated by excluding the out-of-control points. A second study is not required.
7.2.2.3.2 In some instances, control chart analysis may reveal out-of-control conditions that are inherent to the machine/process. Trends due to tool wear or grinding wheel wear are typical examples. If the cause of the out-of-control condition is known, the out-of-control condition is both repeatable and predictable, and the condition cannot be eliminated, the MPC study may be considered acceptable and $C_p$ and $C_{pk}$ values calculated in accordance with 8.1-8.3, or through the use of statistical software.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Machine/Process Average and Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculate the average Range ($R_i$) and the Process Average $\bar{X}$ For the study period, calculate:</td>
<td></td>
</tr>
<tr>
<td>$R_i = \frac{R_1 + R_2 + \ldots + R_k}{k}$</td>
<td></td>
</tr>
<tr>
<td>$\bar{X}_i = \frac{\bar{X}_1 + \bar{X}_2 + \ldots + \bar{X}_k}{k}$</td>
<td></td>
</tr>
<tr>
<td>Where $k$ is the number of subgroups, $R_i$ and $\bar{X}_i$ are the range and average of the first subgroup, $R_i$ and $\bar{X}_i$ are from the second subgroup, etc.</td>
<td></td>
</tr>
</tbody>
</table>

8. Calculating Results
8.1 Estimate the process standard deviation as follows:

$$\sigma = \bar{R}d_2$$

(1)

where:
$d_2 =$ constants for sample size 2 to 10, see Table 2.
8.2 Calculate $C_p$, by dividing the total product tolerance by $6\sigma$.
8.3 Calculate $C_{pk}$ as follows:
9. Analysis of Results

9.1 The qualification of a machine/process shall be based on a review of the statistical parameters C_p and C_p k. C_p and C_p k are both numerical indexes that provide a measure of a process’s variability relative to predefined product specifications. C_p considers the tolerance range only, whereas C_p k considers both the tolerance range as well as how close the process average was to the nominal specification. C_p and C_p k will have the same numerical value when the process average is centered around nominal. As the process average moves away from nominal, C_p k will decrease.

9.2 The decision to accept or qualify a manufacturing process shall be based on the following criteria:

9.2.1 Accept—C_p k equals 1.67 or greater. Process is capable of consistently producing product within specification, if controlled properly, using statistical process control (SPC) techniques.

9.2.2 Conditional Acceptance—C_p k equals 1.33 to 1.67. Machine/process is marginally capable. SPC techniques may be used; however, special care must be taken to ensure that the machine/process average is as close to nominal as possible. Occasional 100 % sorting of product may be required.

9.2.3 Reject—C_p k equals less than 1.33. Process is incapable of producing product within specification. This will require 100 % sorting by the machine/process operator.

9.3 A process with C_p k < 1.33 may also be accepted if both of the following conditions exist:

9.3.1 C_p ≥ 1.67, and

9.3.2 The machine/process is such that the machine/process average can be controlled by the machine operator through normal machine/process adjustments.

9.3.3 The requirements identified in 4.3 shall be imposed on any machine/process that receives conditional acceptance.

9.4 In many cases, capability may vary depending on the degree of control exercised during the study (that is, the type and frequency of adjustments made). The purchaser is responsible for reviewing all adjustments made during the study and ensuring that the same level of control can/will be used in production.

9.5 If the original machine/process capability study is conducted at the equipment vendor’s facility, a follow-up study must be performed after the machine/process is set up and running in the appropriate manufacturing facility to confirm results.

10. Documentation

10.1 It is recommended that documentation of each gage repeatability/reproducibility study and MPC study conducted be maintained and used as a benchmark for continuous improvement of the machine/process.

11. Keywords

11.1 bilateral specification; capability; C_p; C_p k; fasteners; gage capability; inspection plan; machine capability; machine capability study; process capability; process capability study; process parameters; sampling; SPC; statistical process control; unilateral specification

SUMMARY OF CHANGES

This section contains the principal changes to the standard that have been incorporated since the last issue (F 1503 – 95).

(1) Revised the title from Potential to Capability Study, and throughout the body of the standard to reflect current industry practices.

(2) Changed the capability measure index from P_p and P_p k to C_p and C_p k to align the practice with short-run studies.

(3) Removed the figures of variables and individuals control charts.
Designation: F 1554 – 99

Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength


2 Annual Book of ASTM Standards, Vol 01.06.
3 Annual Book of ASTM Standards, Vol 01.01.
4 Annual Book of ASTM Standards, Vol 01.03.

1. Scope

1.1 This specification covers straight and bent, headed and headless, carbon, carbon boron, alloy, or high-strength low-alloy steel anchor bolts (also known as anchor rods). The anchor bolts are furnished in three strength grades, two thread classes, and in the sizes specified in Section 4.

1.2 The anchor bolts are intended for anchoring structural supports to concrete foundations. Such structural supports include building columns, column supports for highway signs, street lighting and traffic signals, steel bearing plates, and similar applications.

1.3 Supplementary requirements are included to provide for Grade 55 weldable steel, permanent manufacturers and grade identification, and impact properties for Grades 55 and 105.

1.4 Zinc coating requirements are included in Section 7 for applications requiring corrosion protection.

1.5 The recommended grade and style of nut and washer are included in 6.6 and 6.7 for each grade.

1.6 This specification does not cover the requirements for mechanical expansion anchors, powder-activated nails or studs, or anchor bolts fabricated from deformed bar.

1.7 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A 194/A194M Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 563 Specification for Carbon and Alloy Steel Nuts

A 673/A673M Specification for Sampling Procedure for Impact Testing of Structural Steel

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel

D 3951 Practice for Commercial Packaging

F 436 Specification for Hardened Steel Washers

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

2.2 Research Council on Structural Connections Standard:

Specification for Structural Joints Using ASTM A325 or A490 Bolts

2.3 ANSI/ASME Standards:

B 1.1 Unified Screw Threads

B 1.3 Screw Thread Gaging Systems for Dimensional Acceptability

B 18.2.2 Square and Hex Nuts

B 18.18.2M Inspection and Quality Assurance for High Volume Machine Assembly Fasteners

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 anchor bolt—a steel rod or bar, one end of which is intended to be cast in concrete, while the opposite end is threaded and projects from the concrete, for anchoring other material to the concrete. The end cast in concrete may be either straight or provided with an anchor such as a bent hook, forged head, or a tapped or welded attachment to resist forces imposed on the anchor bolt, as required.

A 563 Specification for Carbon and Alloy Steel Nuts

A 673/A673M Specification for Sampling Procedure for Impact Testing of Structural Steel

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel

D 3951 Practice for Commercial Packaging

F 436 Specification for Hardened Steel Washers

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
3.1.2 manufacturer—the manufacturer of the anchor bolt; the party that performs the cutting, bending, and threading operations.
3.1.3 producer—the manufacturer of the steel rods or bars.
3.1.4 purchaser—the purchaser of the finished anchor bolt, or his designated agent.
3.1.5 responsible party—see Section 18; this may be the manufacturer or supplier.
3.1.6 supplier—the agent who furnishes the finished anchor bolt and nuts to the purchaser; this may be the manufacturer.

4. Classification
4.1 The anchor bolts are furnished in three grades denoting minimum yield strength and two classes denoting thread class as follows:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Tensile Strength, ksi (MPa)</th>
<th>Yield Strength, min, ksi (MPa)</th>
<th>Size Range, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>36&lt;sup&gt;A&lt;/sup&gt;</td>
<td>58–80 (400–558)</td>
<td>36 (248)</td>
<td>1/4 – 4 (6.4–102)</td>
</tr>
<tr>
<td>55</td>
<td>75–95 (517–655)</td>
<td>55 (380)</td>
<td>1/4 – 4 (6.4–102)</td>
</tr>
<tr>
<td>105</td>
<td>125–150 (862–1034)</td>
<td>105 (724)</td>
<td>1/4 – 9 (6.4–76)</td>
</tr>
</tbody>
</table>

<sup>A</sup> When Grade 36 is specified, a weldable Grade 55 may be furnished at the supplier’s option.

4.2 Weldable steel for Grade 55 is provided for in Supplementary Requirement SI.

5. Ordering Information
5.1 Orders for anchor bolts should include the following information:

5.1.1 Quantity (Number of Pieces)—If the purchaser intends to perform destructive tests on finished anchor bolts, the manufacturer should be advised so that an adequate number are produced, especially for the sizes and types not readily available from stock.

5.1.2 Name of product (steel anchor bolt).
5.1.3 ASTM designation and year of issue.
5.1.4 Grade and class, that is, Grade 36, 55, or 105 and Class 1A or 2A. Weldable Grade 55 may be furnished when Grade 36 is ordered. (See 4.1.)

5.1.5 Copper, if copper bearing steel is required.

5.1.6 Size and Dimensions—Include the diameter and threads (based on nominal thread diameter), bolt length, thread length, and length of hook if a hook is required, or provide a drawing showing the required information.

5.1.7 Zinc coatings in accordance with 7.1. When zinc coatings in accordance with 7.1 are required, specify the zinc coating process to be used, that is, hot dip, mechanically deposited, or no preference. (See 7.1.) Also, specify the length to be coated as measured from the exposed end.

5.1.8 Other Coatings—Specify other protective coatings, if required. (See 7.2.)

5.1.9 Number of nuts, either the total number or number per bolt.

5.1.10 Number of washers, either the total number or number per bolt, and dimensions if other than standard.

5.1.11 Inspection at place of manufacture, if required. (See 15.1.)

5.1.12 Color coding, if different from the standard in 19.1.

5.1.13 Test reports, if required. (See 17.1.)

5.1.14 Supplementary requirements, if required.
5.1.15 Special requirements, if required.

Note 1—An example of a typical order follows: 5000 pieces; steel anchor bolts; ASTM designations including issue date; Grade 55; Class 2A; Supplementary Requirement S 1; 1.0-8-in. thread size by 15-in. long, 3.0-in. thread length, 4.0-in. hook; zinc coated by hot dipping 5.0 in. from exposed end; each with one zinc-coated nut and washer; test report required.

6. Materials and Manufacture

6.1 Process—Steel for anchor bolts shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

6.2 Threading—Threads shall be rolled, cut, or ground at the option of the manufacturer, unless otherwise specified.

6.3 Heat Treatment:
6.3.1 When required, the anchor bolts may be heat treated to develop the specified properties. Heat treatment shall be at the option of the manufacturer.

6.3.2 Heat treatment may be performed prior to or after bending or threading.

6.3.3 When heat treatment is required, the anchor bolts shall be heat treated by quenching in a liquid medium from above the transformation temperature and then tempering by reheating to a temperature not less than 800°F (425°C) for Grade 55 and 1100°F (593°C) for Grade 105.

6.4 Bending:
6.4.1 When required, hooks shall be made by cold bending or hot bending. The bent portion shall be free from cracks when examined at 10× magnification after bending.

6.4.2 Hot bending performed on bar stock without heat treatment shall not have the temperature exceed 1300°F (705°C) at any location during hot bending and shall be allowed to air cool after bending.

6.4.3 Hot bending performed on heat-treated bar stock shall not have the temperature come within 100°F (56°C) of the tempering (stress relieve) temperature of the heat-treat process at any location during hot bending and shall be allowed to air cool after bending.

6.4.4 The bending shall not reduce the cross-sectional area below that required in 10.3.

6.5 Secondary Processing—If a subcontractor, or party other than the manufacturer or producer, performs heat treatment, coating, welding, machining, or other process affecting the properties or performance of the anchor bolts, the anchor bolts shall be inspected and tested after such processing by the party responsible for supplying the anchor bolts to the purchaser.

6.6 Recommended Nuts:
6.6.1 Unless otherwise specified, all nuts used on these anchor bolts shall conform to the requirements of Specification A 194 or A 563 and shall be of the grade, surface finish, and style for each grade and size of anchor bolt as follows:
6.6.2 The requirements for the recommended grade and style of nut may be fulfilled by furnishing a nut of one of the grades or styles listed in Specification A 194 or A 563 having a proof load stress equal to or higher than the minimum tensile strength specified for the anchor bolt.

7. Protective Coatings


7.1.1 When zinc-coated anchor bolts with the coating specified in 7.1 are required, the purchaser shall specify the zinc coating process, for example, hot dip, mechanically deposited, or no preference.

7.1.2 When hot-dip is specified, the fasteners shall be zinc coated by the hot-dip process in accordance with the requirements of Class C of Specification A 153.

7.1.3 When mechanically deposited is specified, the fasteners shall be zinc coated by the mechanical deposition process in accordance with the requirements of Class 50 of Specification B 695.

7.1.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification A 153, Class C, or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process, and the supplier’s option is limited to one process per item, with no mixed processes in a lot.

7.2 Other Coatings:

7.2.1 Coatings other than the zinc coatings specified in 7.1 shall be as specified by the purchaser on the purchase order.

7.2.2 The complete specification shall be included as part of the purchase order when other coatings are specified.

8. Chemical Composition

8.1 Anchor bolts shall have a chemical composition conforming to the requirements listed in Table 1 for Grade 36 and Table 2 for Grades 55 and 105.

8.2 Grade 55 ordered as weldable shall conform to the requirements specified in Supplementary Requirement S1.

8.3 Anchor bolts made from low-carbon martensitic steel shall not be permitted.

8.4 The application of heats of steel to which bismuth, selenium, tellurium, or lead has been added intentionally shall not be permitted.

8.5 Product analyses may be made by the purchaser from finished anchor bolts representing each heat. The chemical composition thus determined shall conform to the requirements specified in 8.1 through 8.4.

9. Mechanical Properties

9.1 Bars—The bars or rods from which the anchor bolts are made shall conform to the tensile properties listed in Table 3, except when heat treated after bending or threading.

9.2 Anchor Bolts—The finished anchor bolts shall conform to the tensile properties listed in Table 3 for tests on machined specimens and Table 4 for axial tests on full-size threaded anchor bolts.

10. Anchor Bolt Dimensions

10.1 Nominal Size—The nominal anchor bolt diameter shall be the same as the nominal thread diameter.

10.2 Body Diameter:

10.2.1 When threads are rolled, the body diameter shall not be less than the minimum pitch diameter for the thread class, 1A or 2A, designated by the purchaser and specified in ANSI/ASME B 1.1. Class 2A shall be furnished when the thread class is not specified.

10.2.2 The body diameter shall not be less than the minimum major diameter when threads are cut.

10.2.3 The minimum body diameters are listed in Table 5 based on the requirements specified in 10.2.1 and 10.2.2.

<table>
<thead>
<tr>
<th>TABLE 1 Chemical Requirements for Grade 36</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>Carbon, max, %</td>
</tr>
<tr>
<td>Manganese, %</td>
</tr>
<tr>
<td>Phosphorus, max, %</td>
</tr>
<tr>
<td>Copper, min, % (when specified)</td>
</tr>
</tbody>
</table>

^a\) Optional with the manufacturer but shall be compatible with weldable steel.
TABLE 2 Chemical Requirements for Grades 55 and 105

<table>
<thead>
<tr>
<th>Element</th>
<th>Composition, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heat Analysis</td>
</tr>
<tr>
<td>Phosphorous, max</td>
<td>0.040</td>
</tr>
<tr>
<td>Sulfur, max</td>
<td>0.050</td>
</tr>
<tr>
<td>Copper, min (when Cu is specified)</td>
<td>0.20</td>
</tr>
<tr>
<td>Copper, min (when Cu is specified)</td>
<td>0.002</td>
</tr>
</tbody>
</table>

TABLE 3 Tensile Properties for Bars and Machined Specimens

<table>
<thead>
<tr>
<th>Grade</th>
<th>36</th>
<th>55</th>
<th>105</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength, ksi</td>
<td>58–80</td>
<td>75–95</td>
<td>125–150</td>
</tr>
<tr>
<td>Tensile strength, MPa</td>
<td>(400–552)</td>
<td>(517–655)</td>
<td>(862–1094)</td>
</tr>
<tr>
<td>Yield strength, min, ksi (0.2 % offset)</td>
<td>36</td>
<td>55</td>
<td>105</td>
</tr>
<tr>
<td>Yield strength, min, MPa (0.2 % offset)</td>
<td>248</td>
<td>380</td>
<td>724</td>
</tr>
<tr>
<td>Elongation in 8 in. (200 mm), min, %</td>
<td>20</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td>Elongation in 2 in. (50 mm), min, %</td>
<td>23</td>
<td>21</td>
<td>15</td>
</tr>
<tr>
<td>Reduction of Area, min, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>¼ to 2 in. (6.4 to 50 mm), incl</td>
<td>40</td>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td>over 2 to 2½ in. (50 to 63 mm), incl</td>
<td>40</td>
<td>22</td>
<td>45</td>
</tr>
<tr>
<td>over 2½ to 3 in. (63 to 76), incl</td>
<td>40</td>
<td>20</td>
<td>45</td>
</tr>
<tr>
<td>over 3 to 4 in. (76 to 102 mm), incl</td>
<td>40</td>
<td>18</td>
<td>. . .</td>
</tr>
</tbody>
</table>

Note: Elongation in 8 in. (200 mm) applies to bars. Elongation in 2 in. (50 mm) applies to tests on machined specimens.

10.3 Bend Section—The bend section of bent anchor bolts shall have a cross-sectional area not less than 90% of the area of straight portions. The area in the bend shall be calculated by the following formula: \( A_b = 0.25\pi D_d \)

where

- \( A_b \) = cross-sectional area in the bend,
- \( d \) = minor (or minimum) diameter at any point, generally in the plane of the bend, and
- \( D \) = major diameter, at the same cross section as, and at 90 degrees to, the minor diameter.

10.4 Length:

10.4.1 The overall length of straight anchor bolts, or length to the inside of the hook, shall be the specified length \( \pm \frac{1}{2} \) in. (13 mm) for lengths 24 in. (600 mm) or less, and \( \pm 1 \) in. (25 mm) for longer bolts (see Fig. 1).

10.4.2 The length of hooks shall be the specified length, \( \pm 10\% \) of the specified hook length, or \( \pm \frac{1}{2} \) in. (13 mm), whichever is greater.

10.5 Bend Angle—The bend angle of hooks shall not vary from that specified by more than \( \pm 5\% \) degrees.

10.6 Coated Length—When only the exposed end of the anchor bolt is required to be zinc coated, the length of zinc coating shall not be less than that specified on the order.

10.7 Other Dimensions:

10.7.1 Tolerances for dimensions other than those given in 10.1 through 10.6 shall be as specified by the purchaser.

10.7.2 When tolerances are not specified, they shall be in accordance with the manufacturer’s documented standard practice.

11. Thread Dimensions

11.1 Uncoated Anchor Bolts:

11.1.1 Unless otherwise specified, uncoated threads shall be Unified Coarse Thread Series as specified in the latest issue of ANSI/ASME B 1.1, and they shall have Class 1A or 2A tolerances, as specified by the purchaser. Class 2A shall be furnished when the class is not specified.

11.1.2 When required, anchor bolts having a nominal diameter greater than 1.0 in. (25.5 mm) may be specified to have threads conforming to the 8-Thread Series (8 UN Series) in ANSI/ASME B 1.1, and they shall have Class 2A tolerances.

11.2 Anchor Bolts Zinc Coated in Accordance With 7.1, Specification A 153, Class C, and Specification B 695, Class 50:

11.2.1 Unless otherwise specified, anchor bolts hot dip or mechanically zinc coated in accordance with 7.1.1 through 7.1.4 (requiring overtapped nuts, see Note 3) shall be the Unified Coarse Thread Series and shall have Class 1A or 2A threads, as specified by the purchaser, before zinc coating. After zinc coating, and due to the zinc buildup, the pitch and major diameters for hot-dip zinc-coated anchor bolts shall not exceed the dimensions listed in Table 6.

Note 3—Zinc-coated nuts of the grade and style recommended in 6.6.1, when overtapped the diametral allowance for the thread series listed in the table entitled “Thread Dimensions and Overtapping Allowances for Nuts” in Specification A 563, will develop the bolt tensile strength required in Table 4 of this specification.

11.2.2 Thread conformance shall be verified during manufacture. In case of dispute, a calibrated thread ring gage of the same size as the oversize limit specified in 11.2.1 (Class X tolerance, gage tolerance plus) shall be used to verify compliance. Assembly of the gage shall be possible with hand effort, following the application of light machine oil to prevent galling and damage to the gage.

11.3 Thread Length—The thread length shall not vary from that specified more than \( +1.0 \) in. (25.5 mm), \( -0.00 \) in. (0.00 mm).

11.4 Thread Gaging System—Thread acceptability shall be in accordance with System 21 or ANSI/ASME B 1.3, unless otherwise specified.

12. Workmanship

12.1 Anchor bolts shall be commercially smooth and free of burrs, laps, seams, cracks, and other injurious manufacturing defects that would make them unsuitable for the intended application.

13. Number of Tests and Retests

13.1 Testing Responsibility:

13.1.1 The anchor bolt manufacturer or supplier, whichever is the responsible party as defined in Section 18, shall be responsible for conducting or ensuring that the required tests have been conducted to determine compliance with all of the requirements of this specification and the purchaser order.

13.1.2 Reports of tension tests, conducted by the steel producer on bar stock used to manufacture the anchor bolts without additional heat treatment, may be used to qualify the finished anchor bolt tensile properties.

13.1.3 The purchaser shall be permitted to perform any of the tests and inspections listed in this specification or the purchaser order.

13.2 Lot Definition:
13.2.1 Bar Stock Tensile Tests—For tensile tests conducted by the steel producer on bars to be used for the manufacture of anchor bolts, a lot shall consist of bars from the same heat, having the same diameter, and, if heat treated, heat treated in the same furnace lot.

13.2.2 All Other Tests—A lot is a quantity of product of one part number made by the same production process and subsequently submitted for final inspection at one time. The maximum lot size traceable to final inspection shall not be larger than 250,000 pieces.

13.3 Test Frequency:

13.3.1 The number of tests shall be as follows and in Table 7 and Table 8:

### TABLE 4 Axial Tensile Properties for Full-Size Anchor Bolts

<table>
<thead>
<tr>
<th>Nominal Size, in.</th>
<th>Threads/ in.</th>
<th>Stress Area, in.²</th>
<th>Anchor Bolt Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>55</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>105</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tensile Strength, B klbf</td>
<td>Yield Strength, min, klbf</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tensile Strength, B klbf</td>
<td>Yield Strength, min, klbf</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tensile Strength, B klbf</td>
<td>Yield Strength, min, klbf</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tensile Strength, B klbf</td>
<td>Yield Strength, min, klbf</td>
</tr>
</tbody>
</table>

Unified Coarse Thread Series (UNC)

<table>
<thead>
<tr>
<th>Nominal Size, in.</th>
<th>Threads/ in.</th>
<th>Stress Area, in.²</th>
<th>Anchor Bolt Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>55</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>105</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tensile Strength, B klbf</td>
<td>Yield Strength, min, klbf</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tensile Strength, B klbf</td>
<td>Yield Strength, min, klbf</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tensile Strength, B klbf</td>
<td>Yield Strength, min, klbf</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tensile Strength, B klbf</td>
<td>Yield Strength, min, klbf</td>
</tr>
</tbody>
</table>

8 Thread Series (8 UN)

<table>
<thead>
<tr>
<th>Nominal Size, in.</th>
<th>Threads/ in.</th>
<th>Stress Area, in.²</th>
<th>Anchor Bolt Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>55</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>105</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tensile Strength, B klbf</td>
<td>Yield Strength, min, klbf</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tensile Strength, B klbf</td>
<td>Yield Strength, min, klbf</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tensile Strength, B klbf</td>
<td>Yield Strength, min, klbf</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tensile Strength, B klbf</td>
<td>Yield Strength, min, klbf</td>
</tr>
</tbody>
</table>

**Notes:**
- Stress areas extracted from ANSI/ASME B 1.1.
- Tensile properties calculated from the tensile requirements given in Table 3.
- Yield strength measured at 0.2 % offset.
- Anchor bolts to 1 ¼ in. (44.5 mm) and larger with 8 UN threads and the nuts overtapped to the limits stated in 11.2.1 will not develop the tensile strength in Table 4 when the bolt and nut dimensions approach the minimum material limits of ANSI/ASME B 1.1 and B 18.2.2. See 11.2.1 for thread series that have been qualified for strength when the nuts are overtapped to the limits stated in 11.2.1.

13.2.1 Bar Stock Tensile Tests—For tensile tests conducted by the steel producer on bars to be used for the manufacture of anchor bolts, a lot shall consist of bars from the same heat, having the same diameter, and, if heat treated, heat treated in the same furnace lot.

13.2.2 All Other Tests—A lot is a quantity of product of one part number made by the same production process and subsequently submitted for final inspection at one time. The maximum lot size traceable to final inspection shall not be larger than 250,000 pieces.

13.3 Test Frequency:

13.3.1 The number of tests shall be as follows and in Table 7 and Table 8:
13.3.2 When the identity to a specific heat number (and furnace lot number for heat-treated bars) has not been maintained, the number of tests for all requirements, including tensile, shall be based on the quantity of anchor bolts of a given description as shown in Table 8.

13.3.3 Tensile tests on finished anchor bolts apply only when bar stock tests are not available or applicable or heat treatment is performed after threading or bending.

13.4 Retests—If a single nonconforming characteristic is found in final inspection, the lot may be resampled for this characteristic with a sample four times the size of the original final acceptance sample. The acceptance criterion shall then be zero discrepancies in this larger sample.

13.5 Purchaser’s Inspection:

13.5.1 If, on receipt of anchor bolts, the purchaser discovers a single nonconforming part, he may sample the lot for such nonconforming characteristic(s) in accordance with 13.3 using an acceptance number of zero.

13.5.2 If the nonconforming characteristic in 13.5.1 is thread dimension and the anchor bolt manufacturer or supplier contests the findings, the final determination of thread acceptability shall be as follows: a full-size axial tension test shall be made on the threaded anchor bolt and nut assembly at the manufacturer’s or supplier’s expense. The assembly shall develop the tensile load specified in Table 4.

14. Test Methods

14.1 Chemical Composition—Chemical analysis shall be conducted in accordance with Test Methods A 751.

### TABLE 5 Minimum Body Diameter

<table>
<thead>
<tr>
<th>Nominal Size, in.</th>
<th>Threads/ in.</th>
<th>Body Diameter, min, in.</th>
<th>Rolled Threads (^a)</th>
<th>Cut Threads (^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Class 1A</td>
<td>Class 2A</td>
</tr>
<tr>
<td>1/4</td>
<td>20 UNC</td>
<td>0.2108</td>
<td>0.2127</td>
<td>0.2367</td>
</tr>
<tr>
<td>3/8</td>
<td>16 UNC</td>
<td>0.3266</td>
<td>0.3287</td>
<td>0.3595</td>
</tr>
<tr>
<td>1/2</td>
<td>13 UNC</td>
<td>0.4411</td>
<td>0.4435</td>
<td>0.4822</td>
</tr>
<tr>
<td>5/8</td>
<td>11 UNC</td>
<td>0.5561</td>
<td>0.5589</td>
<td>0.6052</td>
</tr>
<tr>
<td>3/4</td>
<td>10 UNC</td>
<td>0.6744</td>
<td>0.6773</td>
<td>0.7288</td>
</tr>
<tr>
<td>7/8</td>
<td>9 UNC</td>
<td>0.7914</td>
<td>0.7946</td>
<td>0.8523</td>
</tr>
<tr>
<td>1</td>
<td>8 UNC</td>
<td>0.9097</td>
<td>0.9100</td>
<td>0.9755</td>
</tr>
<tr>
<td>1 1/4</td>
<td>7 UNC</td>
<td>1.0191</td>
<td>1.0228</td>
<td>1.0982</td>
</tr>
<tr>
<td>1 1/2</td>
<td>6 UNC</td>
<td>1.1397</td>
<td>1.1476</td>
<td>1.2232</td>
</tr>
<tr>
<td>1 3/4</td>
<td>5 UNC</td>
<td>1.3772</td>
<td>1.3812</td>
<td>1.4703</td>
</tr>
<tr>
<td>2</td>
<td>4 1/2 UNC</td>
<td>1.6040</td>
<td>1.6085</td>
<td>1.7165</td>
</tr>
<tr>
<td>2 1/2</td>
<td>4 UNC</td>
<td>1.8385</td>
<td>1.8433</td>
<td>1.9641</td>
</tr>
<tr>
<td>2 3/4</td>
<td>3 1/2 UNC</td>
<td>2.0882</td>
<td>2.0931</td>
<td>2.2141</td>
</tr>
<tr>
<td>3</td>
<td>4 UNC</td>
<td>2.3190</td>
<td>2.3241</td>
<td>2.4612</td>
</tr>
<tr>
<td>4</td>
<td>5 UNC</td>
<td>2.5686</td>
<td>2.5739</td>
<td>2.7111</td>
</tr>
<tr>
<td>5</td>
<td>6 UNC</td>
<td>3.0881</td>
<td>3.0734</td>
<td>3.2101</td>
</tr>
<tr>
<td>6</td>
<td>7 UNC</td>
<td>3.5674</td>
<td>3.5730</td>
<td>3.7109</td>
</tr>
<tr>
<td>7</td>
<td>8 UNC</td>
<td>3.8172</td>
<td>3.8229</td>
<td>3.9609</td>
</tr>
</tbody>
</table>

### TABLE 6 Zinc Buildup on Coated Threads and Corresponding Thread Dimensions; Hot-Dip Zinc Coated in Accordance With Specification A 153, Class C

<table>
<thead>
<tr>
<th>Nominal Size, in.</th>
<th>Threads/in.</th>
<th>Diametral Zinc Buildup, in. (^a)</th>
<th>Anchor Bolt Diameter, max, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Anchor Bolt Major</td>
<td>Pitch</td>
</tr>
<tr>
<td>1/4</td>
<td>20</td>
<td>0.016</td>
<td>0.2649</td>
</tr>
<tr>
<td>3/8</td>
<td>16</td>
<td>0.017</td>
<td>0.3907</td>
</tr>
<tr>
<td>1/2</td>
<td>13</td>
<td>0.018</td>
<td>0.5165</td>
</tr>
<tr>
<td>5/8</td>
<td>11</td>
<td>0.020</td>
<td>0.6434</td>
</tr>
<tr>
<td>3/4</td>
<td>10</td>
<td>0.020</td>
<td>0.7682</td>
</tr>
<tr>
<td>7/8</td>
<td>9</td>
<td>0.022</td>
<td>0.8951</td>
</tr>
<tr>
<td>1</td>
<td>8</td>
<td>0.024</td>
<td>1.0220</td>
</tr>
<tr>
<td>1 1/4</td>
<td>7</td>
<td>0.024</td>
<td>1.1469</td>
</tr>
<tr>
<td>1 1/2</td>
<td>8</td>
<td>0.024</td>
<td>1.1468</td>
</tr>
<tr>
<td>1 3/4</td>
<td>7</td>
<td>0.024</td>
<td>1.2719</td>
</tr>
<tr>
<td>2</td>
<td>4 1/2</td>
<td>0.024</td>
<td>1.2718</td>
</tr>
<tr>
<td>2 1/2</td>
<td>4</td>
<td>0.027</td>
<td>1.5248</td>
</tr>
<tr>
<td>2 3/4</td>
<td>3</td>
<td>0.027</td>
<td>1.5246</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>0.050</td>
<td>1.7973</td>
</tr>
<tr>
<td>3 1/2</td>
<td>4</td>
<td>0.050</td>
<td>2.0471</td>
</tr>
<tr>
<td>3 3/4</td>
<td>4</td>
<td>0.050</td>
<td>2.2971</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>0.050</td>
<td>2.5469</td>
</tr>
</tbody>
</table>

\(^a\) These values are the same as the overtap requirements for zinc-coated nuts given in Specification A 563.

---

13.3.2 When the identity to a specific heat number (and furnace lot number for heat-treated bars) has not been maintained, the number of tests for all requirements, including tensile, shall be based on the quantity of anchor bolts of a given description as shown in Table 8.

13.3.3 Tensile tests on finished anchor bolts apply only when bar stock tests are not available or applicable or heat treatment is performed after threading or bending.

13.4 Retests—If a single nonconforming characteristic is found in final inspection, the lot may be resampled for this characteristic with a sample four times the size of the original final acceptance sample. The acceptance criterion shall then be zero discrepancies in this larger sample.

13.5 Purchaser’s Inspection:

13.5.1 If, on receipt of anchor bolts, the purchaser discovers a single nonconforming part, he may sample the lot for such nonconforming characteristic(s) in accordance with 13.3 using an acceptance number of zero.

13.5.2 If the nonconforming characteristic in 13.5.1 is thread dimension and the anchor bolt manufacturer or supplier contests the findings, the final determination of thread acceptability shall be as follows: a full-size axial tension test shall be made on the threaded anchor bolt and nut assembly at the manufacturer’s or supplier’s expense. The assembly shall develop the tensile load specified in Table 4.

14. Test Methods

14.1 Chemical Composition—Chemical analysis shall be conducted in accordance with Test Methods A 751.
14.2 Tensile Tests:
14.2.1 Tensile tests on bars shall be conducted in accordance with Test Methods and Definitions A 370.
14.2.2 Tensile tests on finished anchor bolts shall be conducted in accordance with the Axial Tension Test Method in Method F 606.
14.2.3 Yield strength shall be determined by the 0.2 % offset method.
14.2.4 Tension tests shall be conducted on the bar stock or finished anchor bolt at the manufacturer’s or supplier’s option but shall be conducted after the final heat treatment.
14.2.5 Grades 36 and 55 in sizes 1 1/2 in. (38 mm) and less, and Grade 105 in sizes 1 1/4 in. (32 mm) and less, shall be tested using the full-bar section as rolled or the full-size finished anchor bolt.
14.2.6 Bars and finished anchor bolts larger than those specified in 14.2.5 shall preferably be tested full size, and when so tested the results shall be compared to the tensile properties given in Table 3 for bars and Table 4 for finished anchor bolts. When equipment for full-size testing of these larger sizes is not available, or when the length of the anchor bolt makes full-size testing impractical, standard 0.500-in. (12.7-mm) diameter machined test specimens shall be tested in accordance with Method F 606 and the results compared to the tensile properties given in Table 3.
14.2.7 In the event that anchor bolts are tested by both full-size and machined test specimen methods, the full-size test shall govern if a discrepancy between the two methods exists.
14.3 Zinc Coating—Zinc coating weight and thickness shall be determined in accordance with the methods specified in the applicable zinc coating specifications referenced in 7.1.

15. Inspection
15.1 If the inspection described in 15.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.
15.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer’s works or supplier’s place of business that concern the manufacture or supply of the material ordered. The manufacturer or supplier shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specifications that are requested by the purchaser’s representative shall be made before shipment and shall be conducted so as not to interfere unnecessarily with the operation of the works.

16. Rejection and Rehearing
16.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the manufacturer or supplier may make claim for a rehearing.

17. Certification
17.1 When specified in the purchase order, the manufacturer or supplier, whomever is the responsible party as specified in Section 18, shall furnish the purchaser a test report that includes the following:
17.1.1 Steel producer’s heat analysis and heat number. The carbon equivalent shall be included for bars and anchor bolts ordered in accordance with Supplementary Requirement S 1.
17.1.2 Results of tensile tests.
17.1.3 Zinc coating, measured coating weight, and thickness.
17.1.4 Statement of compliance with dimensional and thread fit requirements.
17.1.5 Certification that the anchor bolts were manufactured and tested in accordance with this specification.
17.1.6 Lot number and purchase order number.
17.1.7 ASTM designation (including year), grade, and class.
17.1.8 Size, description, or purchaser’s drawing number.
17.1.9 Complete mailing address or responsible party.
17.1.10 Title and signature of individual assigned certification responsibility by the company officers.

18. Responsibility
18.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested, and inspected in accordance with this specification and meets all of its requirements.

19. Product Marking
19.1 Unless otherwise specified (see Note 4), the end of each anchor bolt intended to project from the concrete shall be color coded to identify the grade as follows:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>Blue</td>
</tr>
<tr>
<td>55</td>
<td>Yellow</td>
</tr>
<tr>
<td>105</td>
<td>Red</td>
</tr>
</tbody>
</table>

A Extracted from ANSI/ASME B 18.18.2M.
B Visual inspection for type identification, presence of finish, duds, surface discontinuities, and general workmanship.

### Table 7 Inspection Level for Final Inspection

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>Nondestructive Tests</th>
<th>Destructive Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body diameter</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>Head</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Thread acceptance</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>Visual inspection</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>Tensile properties</td>
<td>...</td>
<td>B</td>
</tr>
<tr>
<td>Coating weight/Thickness</td>
<td>B</td>
<td>...</td>
</tr>
</tbody>
</table>

A Extracted from ANSI/ASME B 18.18.2M.

### Table 8 Number of Tests for Final Inspection

<table>
<thead>
<tr>
<th>Lot Size</th>
<th>Level of Inspection</th>
<th>Nondestructive Tests</th>
<th>Destructive Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>999 and less</td>
<td>A</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>1 000 to 5 000</td>
<td>A</td>
<td>50</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>16</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>5 001 to 250 000</td>
<td>A</td>
<td>100</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>32</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>8</td>
<td>1</td>
</tr>
</tbody>
</table>

A Extracted from ANSI/ASME B 18.18.2M.

### Table 9 Color Coding

<table>
<thead>
<tr>
<th>Grade</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>Blue</td>
</tr>
<tr>
<td>55</td>
<td>Yellow</td>
</tr>
<tr>
<td>105</td>
<td>Red</td>
</tr>
</tbody>
</table>

Color coded to identify the grade as follows:

- **36** Blue
- **55** Yellow
- **105** Red
NOTE 4—This color coding is intended to facilitate locating the proper grade of anchor bolt at its designed location. The color code also identifies the grade at delivery and at final field inspection. When other color coding is required to define diameter, configuration, dimensions, etc., see 19.2.

19.2 When color coding other than specified in 19.1 is required, it shall be specified on the inquiry and purchase order.

19.3 When permanent manufacturers identification, or permanent grade identification, or both are required, Supplementary Requirement S2 or S3, or both, as needed, shall be specified on the inquiry and purchase order.

20. Packaging and Package Marking

20.1 Packaging:
20.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.
20.1.2 When zinc-coated nuts are included on the same order as zinc-coated anchor bolts, the anchor bolts and nuts shall be shipped in the same container.
20.1.3 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

20.2 Package Marking:
20.2.1 Each shipping unit shall include or be marked plainly with the following information:
   20.2.1.1 ASTM designation, Grade, and Class;
   20.2.1.2 Size;
   20.2.1.3 Name and brand or trademark of the manufacturer;
   20.2.1.4 Number of pieces;
   20.2.1.5 Lot number;
   20.2.1.6 Purchase order number; and
   20.2.1.7 Country of origin.

21. Keywords
21.1 anchor bolts; steel

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified in the purchase order or contract:

S1. Grade 55 Bars and Anchor Bolts

S1.1 The material described in this section is intended for welding. This supplemental section, by chemical composition restrictions and by a carbon equivalent formula, provides assurance of weldability.

S1.2 Welding technique is of fundamental importance when bolts produced to this supplementary section are welded. It is assumed that suitable welding procedures for the steel being welded and the intended service will be selected.

S1.3 The requirements of this supplementary requirement supersede conflicting provisions of the general specification.

S1.4 Because of the embrittling effects of welding temperatures on cold-forged steel, this supplemental section is limited to hot-forged bolts, or, if not forged, to the thread bars, studs, or bolts produced from hot-rolled bars without forging. Cold-forged bolts or cold-drawn threaded bars are suitable if they are given a thermal treatment by heating to a temperature of not less than 1500°F (815°C) and air-cooled.

S1.5 Chemical Composition:

<table>
<thead>
<tr>
<th>Heat Analysis</th>
<th>Product Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon, max, %</td>
<td>0.30</td>
</tr>
<tr>
<td>Manganese, max, %</td>
<td>1.35</td>
</tr>
<tr>
<td>Phosphorus, max, %</td>
<td>0.040</td>
</tr>
<tr>
<td>Sulfur, max, %</td>
<td>0.050</td>
</tr>
<tr>
<td>Silicon, max, %</td>
<td>0.50</td>
</tr>
</tbody>
</table>

S1.5.2 Carbon Equivalent—In addition to the requirements specified in S1.5.1, the analysis shall be such as to provide a carbon equivalent (CE) meeting the following requirements:

S1.5.2.1 For alloy or low-alloy steel, the carbon equivalent shall not exceed 0.45 % when calculated as follows:

\[
CE = \% C + \frac{\% Mn}{6} + \frac{\% Cu}{40} + \frac{\% Ni}{20}
\]

\[
+ \frac{\% Cr}{10} + \frac{\% Mo}{50} + \frac{\% V}{10}
\]

S1.5.2.2 For carbon steel, the carbon equivalent shall not exceed 0.40 % when calculated as follows:

\[
CE = \% C + \frac{\% Mn}{4}
\]

S1.6 Marking—Each anchor bolt conforming to this supplementary requirement S1 shall be designated by a white paint mark on the side of the bar near the end to be encased in concrete.

S2. Permanent Manufacturer’s Identification

S2.1 The end of the anchor bolt intended to project from the concrete shall be steel die stamped with the manufacturer’s identification. Marking small sizes (customarily less than 0.375 in. (9.525 mm)) may not be practical. Consult the anchor bolt manufacturer for the minimum size that can be marked.

S2.2 When required, grade and manufacturer’s or private label distribution’s identifications shall be separate and distinct. The two identifications shall preferably be in different locations and shall be separated by at least two spaces when on the same level.

S3. Permanent Grade Identification

S3.1 Instead of color coding as specified in 19.1, the end of the anchor bolt intended to project from the concrete shall be steel die stamped with the grade identification as follows:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>AB36</td>
</tr>
<tr>
<td>55</td>
<td>AB55</td>
</tr>
</tbody>
</table>
S3.2 The requirements given in S2.1 for marking small sizes, and, in S2.2 that grade and manufacturer’s identifications be separate and distinct, shall also apply to this supplementary requirement.

S4. Grades 55 and 105 Charpy Impact Requirements at +40°F (+5°C)

S4.1 Grades 55 and 105 shall have a Charpy V-Notch impact strength conforming to the requirements listed in Table S1.1.

S4.2 Tests shall be conducted in accordance with Test Methods and Definitions A 370.

S4.3 Notch toughness tests shall be performed at the Test Frequency P (Piece Testing) of Specification A 673 on finished anchor bolts when the results of notch toughness tests are not available on bar stock.

S4.4 Notch toughness tests shall be performed at the Test Frequency H (Heat Lot Testing) of Specification A 673 on bar stock, except when heat treatment is performed after threading or bending, in which case the tests shall be those required in S4.3.

S5. Grade 105 Charpy Impact Requirements at −20°F (−29°C)

S5.1 Grade 105 shall have Charpy V Notch impact strength conforming to the requirements listed in Table S1.2.

S5.2 Test methods and frequency of testing shall be as specified in S4.2 through S4.4.

**TABLE S1.1 Energy and Test Temperature Requirements**

<table>
<thead>
<tr>
<th>Charpy V-Notch Energy Requirements</th>
<th>Test Temperature, °F (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average for 3 Specimens, min, ft·lbf (J)</td>
<td>Minimum for 1 Specimen, ft·lbf (J)</td>
</tr>
<tr>
<td>15 (20)</td>
<td>12 (16)</td>
</tr>
</tbody>
</table>

**TABLE S1.2 Energy and Test Temperature Requirements**

<table>
<thead>
<tr>
<th>Charpy V-Notch Energy Requirements</th>
<th>Test Temperature, °F (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average for 3 Specimens, min, ft·lbf (J)</td>
<td>Minimum for 1 Specimen, ft·lbf (J)</td>
</tr>
<tr>
<td>15 (20)</td>
<td>12 (16)</td>
</tr>
</tbody>
</table>

**SUMMARY OF CHANGES**

This section identifies the location of selected changes to this standard that have been incorporated since the –97 issue. For the convenience of the user, Committee F-16 has highlighted those changes that impact the use of this standard. This section may also include descriptions of the changes or reasons for the changes, or both.

1. In 1.1 recognized “anchor bolts” are also known as “anchor rods”.
2. Added 5.1.12 for ordering color codes other than standard.
3. Revised 19.1 and added 19.2 to recognize other color codes may be ordered.
4. Added 19.3 as a pointer to S2 and S3 for permanent grade and manufacturer’s marks.
5. Revised S3.1 to clarify paint coating is not required when permanent grade marking is specified and to define the grade marking.

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Standard Test Method for Determining Bending Yield Moment of Nails

This standard is issued under the fixed designation F 1575; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope *

1.1 This test method covers procedures for determining the bending yield moment of nails when subjected to static loading. It is intended only for nails used in engineered connection applications, in which a required connection capacity is specified by the designer.

1.2 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
E 4 Practices for Force Verification of Testing Machines
F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
F 1667 Specification for Driven Fasteners: Nails, Spikes, and Staples

3. Terminology

3.1 Definitions of Terms Specific to This Standard:
3.1.1 bending yield moment—the moment determined from the load-deformation curve that is intermediate between the proportional limit and maximum load for the nail. It is calculated by the intersection of the load-deformation curve with a line represented by the initial tangent modulus offset 5% of the fastener diameter.

3.1.2 transition zone—the location of the transition from smooth shank to threaded shank on a deformed-shank nail.

3.1.3 yield theory—the model for lateral load design values for dowel-type fasteners that specifically accounts for the different ways these connections behave under load. The capacity of the connection under each yield mode is determined by the bearing strength of the material under the fastener and the bending strength of the fastener, with the lowest capacity calculated for the various modes being taken as the design load for the connection.

4. Summary of Test Method

4.1 Test specimens are evaluated to determine capacity to resist lateral bending loads applied at a constant rate of deformation with a suitable testing machine. The load on the test specimen at various intervals of deformation is measured. Supplementary physical properties of the test specimen are also determined.

5. Significance and Use

5.1 Nails are a common mechanical fastener in wood structures. Engineering design procedures used to determine the capacities of laterally-loaded nailed connections currently use a yield theory to establish the nominal resistance for laterally-loaded nailed connections that are engineered. In order to develop the nominal resistance for laterally-loaded nailed connections, the bending yield moment must be known.

6. Apparatus

6.1 Testing Machine—Any suitable testing machine capable of operation at a constant rate of motion of its movable head and having an accuracy of ±1% when calibrated in accordance with Practice E 4.

6.2 Cylindrical Bearing Points—Any cylindrical metal member capable of supporting the test specimen during loading without deforming, as shown in Fig. 1, and having diameter \( D = 0.375 \text{ in.} \)

6.2.1 Cylindrical bearing points shall be free to rotate as the test specimen deforms.

6.3 Cylindrical Load Point—Any cylindrical metal member capable of loading the test specimen without deforming, as shown in Fig. 1, and having diameter \( D = 0.375 \text{ in.} \)

6.4 Recording Device—Any device with at least a reading of 0.001 in. (0.025 mm) and any suitable device for measuring the load on the test specimen during deformation.

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1 This test method is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.05 on Driven and Other Fasteners.


2 Annual Book of ASTM Standards, Vol 03.01.

3 Annual Book of ASTM Standards, Vol 01.08.

*A Summary of Changes section appears at the end of this standard.
7. Sampling

7.1 Sampling shall provide for selection of representative test specimens that are appropriate to the objectives of the testing program.

8. Specimens and Tests

8.1 Tests for smooth shank nails shall be performed on either the finished nail or a specimen of drawn wire stock from which the nail would be manufactured. Tests for deformed-shank nails shall be performed on the finished nail.

8.2 Diameter Measurement—Measure the actual diameter of each test specimen at the midpoint of its length to the nearest 0.001 in. (0.025 mm). The nail diameter shall be defined as the diameter of the unthreaded shank for partially deformed-shank nails and shall be measured at the midpoint of the length of nail shank between nail head and transition zone.

8.3 Length Measurement—The nail shall be long enough to prevent the nail head or point from bearing on the cylindrical nail supports during application of load to the nail through the time when ultimate load is reached.

9. Procedure

9.1 Test Setup:

9.1.1 Cylindrical bearing point spacing, \( s_{bp} \), shall be as indicated in Table 1

9.1.1.1 If nails are too short to meet this requirement and the nails receive no processing after forming that can affect fastener bending yield strength, such as heat treating or thread rolling, the test shall be performed on wire from which the nail is made.

9.1.1.2 If nails are too short to meet this requirement and receive processing after forming that can affect fastener bending yield strength, such as heat treating or thread rolling, the nails shall be tested with the largest possible span and the span and circumstances reported in the report.

Note: Experience indicates that test results are sensitive to large changes in bearing point spacing, \( s_{bp} \).

9.1.2 The load shall be applied to the test specimen so that the center of the cylindrical load point is equidistant from the center of each cylindrical bearing point \( (s_{bp}/2) \) as shown in Fig. 1.

9.1.3 Deformed-shank nails shall be placed on the cylindrical bearing points for testing so that the transition zone between shank and thread is as close to the midpoint between the bearing points as possible.

9.2 Loading:

9.2.1 The maximum constant rate of loading, \( r_L \), shall be as follows:

\[ r_L = 0.25 \text{ in./min} \]

9.2.2 The procedures described herein are for static loading. Procedures to evaluate nails for impact or cyclic loads are not a part of this test method.

9.3 Load and Deformation Measurement—Measure the applied load on and deformation of the test specimen from the initiation of load application and take readings of each at sufficiently frequent intervals to permit establishment of a satisfactory load-deformation curve except as permitted in 9.3.1. Continue the loading until the ultimate load is reached and the load capacity begins to decrease.

9.3.1 As an alternative to establishment of a load-deformation curve, initial tests shall be performed to establish a relationship between ultimate load and the 5 % offset value in accordance with 10.1. The ultimate load only shall then be recorded for subsequent tests.

10. Interpretation of Results

10.1 The bending yield moment is determined by fitting a straight line to the initial linear portion of the load-deformation curve, offsetting this line by a deformation equal to 5 % of the nail diameter, and selecting the load at which the offset line intersects the load-deformation curve (see Fig. 2). In those cases where the offset line does not intersect the load-deformation curve, the maximum load shall be used as the yield load. The bending yield moment shall be the average of the specimens tested.

11. Report

11.1 Report the following information:

11.1.1 Tabulated and plotted data on load-deformation relationships or ultimate load and the ultimate/5 % offset load relationship in accordance with 9.3.1,
11.1.2 Physical description of the test specimen including diameter and thread characteristics for deformed-shank nails,
11.1.3 Location of transition zone for deformed-shank nails between load points,
11.1.4 Rate of loading, and
11.1.5 Number of replicate tests.

12. Precision and Bias

12.1 The precision and bias of this test method has not yet been determined.

13. Keywords

13.1 bending yield moment; fastener; nail; yield; yield theory

ANNEX

(Mandatory Information)

A1. DERIVATION OF BENDING YIELD STRENGTH DESIGN VALUES, $F_{yb}$

A1.1 The nominal bending yield strength shall be determined by the following:

$$F_{yb} = \frac{M_y}{S}$$

where

- $F_{yb}$ = nominal fastener yield strength, psi,
- $S$ = effective plastic section modulus (in.$^3$) for full plastic hinge (for circular, prismatic nails, $S = \frac{D^3}{6}$, where $D$ = nail diameter), and
- $M_y$ = calculated moment based on test load, in.-lb
  \[ \frac{P \cdot s_{bp}/4}{4} \]

where

- $P$ = test load as determined from load-deformation curve, as shown in Fig. 2 or as specified in 9.3.1, lb, and
- $s_{bp}$ = cylindrical bearing point spacing as shown in 9.1.1, in.

APPENDIX

(Nonmandatory Information)

X1. COMMENTARY

X1.1 This is a test method to evaluate bending yield moment of nails for design and is not intended to be a nail manufacturing test procedure for quality control. This test method provides a means for determining bending yield strength, $F_{yb}D$, so that the supplier/manufacturer is aware of the full requirements for the product being provided.

X1.2 In accordance with 6.2 and 6.3, preliminary studies indicate that loading head and support diameters do not show a significant radius effect on material properties. The diameter shown in this test method is based on one of the larger nails produced, with a $\frac{3}{8}$-in. diameter.

X1.3 In accordance with 7.1, the number of samples to test to provide for a representative selection should be agreed upon by the nail manufacturer and customer. Guide F 1470 provides guidance in this area.

X1.4 Centers of the cylindrical bearing points shall remain in the specified position (spacing) during testing. This can be accomplished by using a jig described in The Testing of...
Improved Nails, ASTM Materials Research and Standards.\textsuperscript{4}

X1.5 In accordance with 9.2.1, the 0.25-in./min load rate shown in this test method is roughly based on one nail diameter per minute. Several European studies indicate that small changes in rate of loading do not show a significant effect on material properties.

X1.6 In accordance with 9.3.1, the option for establishing a relationship between ultimate load and the 5\% offset value allows simplification of testing. Once the relationship is established with preliminary tests, ultimate load alone can be measured and recorded for each test. Periodic verification by the manufacturer will ensure accurate establishment of 5\% offset design values.

\begin{center}
\textbf{SUMMARY OF CHANGES}
\end{center}

Committee F16 has identified the location of selected changes to this standard since the last issue (F 1575 – 01) that may impact the use of this standard (approved October 10, 2002).

(1) Paragraph 9.1.1 was modified and Table 1 added. A table previously part of Figure 1 was deleted. This changed the cylindrical bearing point spacing to equal 11.5 nail diameters.
(2) Paragraphs 9.1.1.1 and 9.1.1.2 and Note 1 were added and subsequent sections were renumbered. This addresses an exception to recommendations on cylindrical bearing point spacing.
(3) Paragraph 11.1.2 was modified to delete “carbon content of steel” as information to be reported.
(4) The first two sentences of X1.4 were deleted.

Committee F16 has identified the location of selected changes to this standard since the last issue (F 1575 – 02) that may impact the use of this standard (approved May 10, 2003).

(1) Column heading in Table 1 was modified.
(2) Diameter added to Table 1.
(3) Section 3.1.3 was deleted and subsequent sections renumbered.

\\textsuperscript{4} Available from University Microfilms, Inc., 300 N. Zeeb Road, Ann Arbor, MI 48106, Vol 6, No. 12, pp. 602–607, December 1966.
Standard Specification for Driven Fasteners: Nails, Spikes, and Staples

This standard is issued under the fixed designation F 1667; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. The Commercial and Government Entity (Cage) Code for ASTM: 81346.

1. Scope

1.1 This specification covers nails, spikes, staples, and other driven fasteners, as listed in Table 1.

Note 1—Fastener ductility information is presented in Table 2 and dimensional information in Tables 3-63.

1.2 Fasteners described in this specification are driven by hand tool, power tool, or mechanical device in single or multiple strikes and are positioned by hand, tool, or machine.

1.3 The values stated in inch-pound units are to be regarded as the standard.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
A 641/A 641M Specification for Zinc-Coated (Galvanized) Carbon Steel Wire
B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
F 547 Terminology of Nails for Use with Wood and Wood-Base Materials
F 592 Terminology of Collated and Cohered Fasteners and Their Application Tools
F 680 Test Methods for Nails
F 1575 Test Method for Determining Bending Yield Moment of Nails

3. Terminology

3.1 Definitions—The definitions used in this specification are those of common commercial acceptance and usage and also appear in Terminologies F 547 and F 592.

4. Classification

4.1 The fasteners and their Table 1 classification are identified as follows:

Note 2—The identification of fasteners, classified by style and type (alpha indicators) followed by a dash number (numerical code) based on Tables 3-63, identifies dimensions specifically and establishes a PIN (part identifying number) system when preceded by the F 1667 ASTM designer of this specification. For example:

```
F 1667 NL CL-09  Identifies a cooler nail with a length of 2 5/8, a shank diameter of 0.120, and a head diameter of 0.297 (See Table 10).
```

4 All dimensions are given in inches.

4.2 The trade designation, $, pennyweight, used in commercial practice is referenced in Tables 3-63 wherever it applies.

5. Ordering Information

5.1 Orders for driven fasteners under this specification shall include the following information:

5.1.1 Quantity or weight;
5.1.2 Part identifying number (PIN) or product description (see 4.1 and appropriate table);
5.1.3 Special material requirements, if specified, including coatings or finishes;
5.1.4 ASTM designation;
5.1.5 Packaging requirements;
5.1.6 A producer’s or supplier’s certification that the material and the finished fastener are in compliance with this specification, furnished only when specified in the purchase order;

5.1.7 Supplementary requirements, if any; and

5.1.8 Any additions agreed upon between the purchaser and the supplier.

6. Material Requirements

6.1 Steel wire used in the manufacture of driven fasteners shall be of low carbon, medium-low carbon, or medium-high carbon.

6.2 Stainless steel wire used in the manufacture of driven fasteners shall be of Types 302, 304, 305, or 316.

6.3 Carbon steel wire for the manufacture of hardened steel nails shall be suitable for heat treatment to a minimum hardness of 37 HRC.

6.4 Sheet steel used in the manufacture of cut nails (Type II) and cut spikes, Type III shall be a medium-carbon sheet steel.

6.5 Copper used in the manufacture of driven fasteners shall contain a minimum of 98 % pure copper.

6.6 Copper-clad steel wire used in the manufacture of driven fasteners shall contain not less than 20 % copper by weight. The average thickness of copper on the steel wire shall be not less than 10 % of the radius of the clad wire; the minimum thickness of copper on the steel wire shall be not less than 8 % of the radius of the clad wire.

6.7 Aluminum alloy wire used in the manufacture of fasteners shall conform to Alloy 2024, 5056, 6061, or 6110 and have a minimum ultimate tensile strength of 60 000 psi.

6.8 Brass wire used in the manufacture of fasteners shall be of good commercial quality suitable for the purpose.

7. Physical Properties

7.1 Ductility—The fasteners shall be sufficiently ductile to withstand cold bending without fracture, as specified in Table 2 for various materials used in the manufacture of fasteners utilizing the conventional bend test described in Test Methods F 680. Mandrel diameter used in this test shall not exceed nail/wire diameter. The cold bend test shall not apply to unhardened nails with deformed shanks.

7.2 Tensile Strength—Finished driven fasteners are not normally subject to tension testing. However, the wire or sheet
used to manufacture the fastener is tested as required for control in the production process during manufacture.

8. Dimensions and Tolerances

8.1 Nominal dimensions of nails and spikes shall be as shown in Tables 3-55. The following dimensional designations shall apply:

\[ S = \text{trade designation (reference in penny weight)}, \]
\[ L = \text{length, in.}, \]
\[ H = \text{head diameter or width, in.}, \]
\[ D = \text{shank diameter, in.}, \]
\[ B = \text{head separation, in. (Table 18), and} \]
\[ \text{No./lb} = \text{approximate count per pound}. \]

8.1.1 The lengths, \( L \), of nails and spikes with flat heads or parallel shoulders under the head shall be measured from under the head or shoulder to the tip of the point. All other nails and spikes shall be measured overall.

8.1.2 The diameter, \( D \), of smooth shank nails and spikes shall be measured away from the gripper marks. The diameter, \( D \), of formed or deformed shanks shall be measured before deformation, or, if specified, the thread crest diameter after deformation, or both. All diameter dimensions shall be taken prior to the application of or after the removal of any coatings or finish.

8.2 Tolerances on Nominal Dimensions for Nails and Spikes:

8.2.1 Length tolerances shall be \( \pm \frac{1}{32} \) in. for lengths up to and including 1 in.; \( \pm \frac{1}{64} \) in. for lengths over 1 in., up to and including 2\( \frac{1}{2} \) in.; \( \pm \frac{1}{64} \) in. for lengths over 2\( \frac{1}{2} \) in., up to and including 7 in.; and \( \pm \frac{1}{64} \) in. for all lengths over 7 in.

8.2.2 Shank diameter tolerances shall be \( \pm 0.002 \) in. for diameters smaller than 0.076 in. and \( \pm 0.004 \) in. for diameters 0.076 in. and larger.

8.2.3 Head Diameter Tolerances:

8.2.3.1 Hand Driven—Tolerances on head diameters of roofing nails shall be \( \pm 0, -10 \% \) of the nominal head diameter (the mean of two readings 90\(^\circ\) apart). For other brads, nails, and spikes, the tolerance shall be \( \pm 10 \% \) of the nominal head diameter (individual measurement). The difference in diameter across the long axis of a roofing nail shall not exceed that across the short axis by more than 20 \%. For other brads, nails, and spikes, the difference in diameter across the long axis shall not exceed that across the short axis by more than 10 \%. A fillet shall be provided under the head if not otherwise specified.

8.2.3.2 Power Driven—Tolerances on head diameters of power-driven nails shall comply with the manufacturer’s specifications and shall be suitable for use in the make and model of the tool specified.

8.3 Nominal dimensions of staples shall be as shown in Tables 56-63, and the following dimensional designations shall apply:

8.3.1 Hand Tool–Driven Nominal Dimensions:

\[ L = \text{leg length, inside, in.}, \]
\[ D = \text{round leg diameter, in.}, \]
\[ C = \text{crown width, inside, in.}, \] and
\[ \text{No./lb} = \text{approximate count per pound}. \]

8.3.2 Power Tool–Driven Nominal Dimensions:

\[ D = \text{round leg diameter, in.}, \]
\[ L = \text{leg length, outside, in.}, \]
\[ T = \text{leg thickness, in. (see Tables 58 and 59),} \]
\[ W = \text{leg width, in. (see Tables 58 and 59),} \]
\[ C = \text{crown width, outside, in.}, \] and
\[ G = \text{steel wire gage}. \]

8.4 Tolerances on Nominal Dimensions for Staples:

8.4.1 Leg length, \( L \), tolerances shall be \( +\frac{1}{32}, -\frac{1}{64} \) in. for both hand tool–driven and power tool–driven staples.

8.4.2 Diameter tolerances for hand tool–driven round staples shall be \( \pm 0.002 \) in. for diameters smaller than 0.076 in. and \( \pm 0.004 \) in. for diameters 0.076 in. and larger.

8.4.3 Thickness and width tolerances on power-driven staples shall comply with the manufacturer’s specification and shall be suitable for use in the make and model tool specified (see Tables 58 and 59).

8.4.4 Crown width tolerances are \( \pm \frac{1}{2} \) in. unless otherwise specified.

8.5 Nominal Dimensions for Cut Nails, Type II—Unless otherwise specified, cut nails shall be sheared from medium carbon sheet steel and shall have a wedge-shaped shank with a sheared square point end narrower than the upset head end. The designation \( T \) in Tables 45-50 refers to sheet thickness in finished product. Other designations shall be the same as those for nails in 8.1.

8.6 When gage is used for a nominal diameter dimension in the application of this specification, it shall be in accordance with the decimal equivalents as shown in Specification A 510, unless otherwise specified.

9. Workmanship

9.1 Fasteners covered by this specification shall be true to shape, well-finished, free from imperfections, clean, and free of corrosion. Mechanically driven collated items shall be uniform and aligned properly in their assembled form for use in power tools.

10. Protective Coatings and Finishes

10.1 Zinc Coating:

10.1.1 Driven fasteners required to be zinc coated shall be cut and formed from hot-dip, hard-wiped, galvanized steel wire, electrogalvanized steel wire, or zinc flake/chromate dispersion-coated steel wire; or they shall be cut from uncoated (bright) steel wire and shall be hot-dip galvanized, electrodeposited zinc coated, mechanically deposited zinc coated, or zinc flake/chromate dispersion coated after forming. Power-driven staples are not normally zinc coated after forming.

10.1.2 Hot-dip galvanized or electrogalvanized steel wire for the manufacture of fasteners shall have a coating weight in accordance with Specification A 641, Supplementary Requirements, Class 1.

10.1.3 Hot-dip galvanized steel fasteners coated after forming shall have a coating weight in accordance with Specification A 153, Class D, when a heavier coating for exterior use is
specified. If not otherwise specified, the coating weight shall be in accordance with Specification A 641, Supplementary Requirements, Class 1.

10.1.4 Mechanically deposited zinc coatings applied to fasteners after forming shall have a thickness in accordance with Specification B 695, Class 40, unless otherwise specified.

10.2 Other Coatings and Finishes (When Specified):

10.2.1 Cement coating shall be applied by tumbling, mechanical dispensing device, or immersion in resin or other similar material and shall not be tacky or gummy. Cement coatings on power-driven fasteners shall be uniform and applied before, during, or after the fasteners are cohered into strips, clips, or coils.

Note: 4—Cement coatings increase the holding strength in withdrawal of a driven fastener, depending on the fastener size, amount of cement coating applied, and method of driving.

10.2.2 Chemical etching shall remove the polish of fabrication and roughen the surface microscopically.

10.2.3 Blued nails shall be heated to form a thin, colored oxide on the surface.

10.2.4 Miscellaneous finishes, such as tin plating, liquor, brass plating, copper plating, phosphate coating, or oil coating shall be applied.

10.3 Altered Shapes and Deformations:

10.3.1 Mechanically formed or deformed nail shanks shall have barbs, flutes, threads, or angular serrations formed onto the wire from which the nail is manufactured. Mechanically deformed shanks shall have vertical or helical flutes or screw-type or annular (ring)-type deformations rolled onto the shank. Symmetrical helical shank deformations shall be obtained by twisting square wire. The deformations shall pass entirely around the shank body, resulting in expanded ridges and depressions.

10.3.2 Mechanically formed or deformed nail heads shall be round or T-headed; or they shall be altered round for suitable use in a given make and model of a power-driving fastening system.

10.3.3 Staples manufactured for intended use in power tools shall comply with the tool manufacturer’s specification or Type IV, Style 3 (Table 58 or Table 59).

11. Certification

11.1 When specified in the purchase order, a producer’s or supplier’s certification shall be furnished to the purchaser, indicating that the fasteners are in compliance with this specification and the purchase order.

12. Packaging and Package Marking

12.1 Unless otherwise specified, fasteners shall be in substantial commercial containers of the type, size, and kind commonly used for the purpose, so constructed as to preserve the contents in good condition and to ensure acceptance and safe delivery by common or other carriers to the point of delivery. In addition, the containers shall be so made that the contents can be removed partially without destroying the container’s ability to serve as a receptacle for the remainder of the contents.

12.2 When specified, individual packages and shipping containers shall be marked with the part-identifying number and type, length, diameter (or gage, as applicable) of the fastener, the name of the manufacturer or distributor, and the quantity or net weight.

13. Keywords

13.1 diameter; driven fasteners; head; length; nails; point; spikes; staples
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified in the order or contract (5.1.7). Details of these supplementary requirements shall be agreed upon in writing between the manufacturer and the purchaser.

S1. Nail Bending Yield Strength

S1.1 When specified as a supplementary requirement for nails used for engineered construction, the nail’s average bending yield strengths shall meet, as a minimum, the yield strengths used in determining the lateral design loads tabulated in the AF&PA National Design Specification\(^6\) for Wood Construction, NDS,\(^6\) Part XII: Nails and Spikes.

S1.2 The minimum average bending yield strengths used by the NDS\(^6\) as a function of the material and diameter of the nail are given in Table S1.1 and Table S1.2.

S1.3 Test Method for Yield Strength—In order to conform with the supplementary requirements of S1, the procedure of Test Method F 1575 shall be conducted on nail samples.

S1.4 At least five nails from each lot of 100 individual containers shall be examined and tested to determine conformance with this supplementary requirement.

S1.5 When labeled “Engineered Construction Nails, ASTM F 1667,” nails must meet all requirements of F 1667 including Supplementary Requirements.


### TABLE S1.1 Low to Medium Carbon Steel Nails and Spikes

<table>
<thead>
<tr>
<th>Nominal Diameter, in.</th>
<th>Bending Yield, psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.099 ≤ 0.142</td>
<td>100 000</td>
</tr>
<tr>
<td>&gt;0.142 ≤ 0.177</td>
<td>90 000</td>
</tr>
<tr>
<td>&gt;0.177 ≤ 0.254</td>
<td>80 000</td>
</tr>
<tr>
<td>&gt;0.254 ≤ 0.273</td>
<td>70 000</td>
</tr>
<tr>
<td>&gt;0.273 ≤ 0.344</td>
<td>60 000</td>
</tr>
<tr>
<td>&gt;0.344 ≤ 0.375</td>
<td>45 000</td>
</tr>
</tbody>
</table>

### TABLE S1.2 Medium Carbon Steel Nails—Hardened

<table>
<thead>
<tr>
<th>Nominal Diameter, in.</th>
<th>Bending Yield, psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.120 ≤ 0.142</td>
<td>130 000</td>
</tr>
<tr>
<td>&gt;0.142 ≤ 0.192</td>
<td>115 000</td>
</tr>
<tr>
<td>&gt;0.192 ≤ 0.207</td>
<td>100 000</td>
</tr>
</tbody>
</table>

SUMMARY OF CHANGES

Subcommittee F16.05 has identified the location of selected changes to this standard since the last issue (F 1667 - 02) that may impact the use of this standard (approved December 10, 2002).

1. Wording which might be considered “permissive” was deleted from paragraphs 1.2, 10.2.1, and 10.3.1.

2. Note B at the bottom of Table 58 was revised so that staple leg cross section dimensions would reflect industry practice.

Subcommittee F16.05 has identified the location of selected changes to this standard since the last issue (F 1667 - 02a) that may impact the use of this standard (approved May 10, 2003).

1. Table references in Section 8.3.2 and 8.4.3 were revised.

2. Added dash numbers 38 through 82 to Table 16.
TABLE 3 Type I, Style 1—Brads

Note—Steel wire, brad head, diamond point, round smooth shank, bright finish. When specified, brads shall have a modified brad head with a blunt or chiseled point for use with mechanical drivers.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>S</th>
<th>No./lb</th>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>S</th>
<th>No./lb</th>
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</thead>
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<td>...</td>
<td>670</td>
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<td>02</td>
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<td>0.035</td>
<td>...</td>
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<td>1 1/4</td>
<td>0.080</td>
<td>...</td>
<td>400</td>
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<td>0.080</td>
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<td>06</td>
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<td>30</td>
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<td>33</td>
<td>3 1/4</td>
<td>0.148</td>
<td>12d</td>
<td>65</td>
</tr>
<tr>
<td>14</td>
<td>1/16</td>
<td>0.072</td>
<td>...</td>
<td>904</td>
<td>34</td>
<td>3 1/2</td>
<td>0.162</td>
<td>15d</td>
<td>50</td>
</tr>
<tr>
<td>15</td>
<td>5/64</td>
<td>0.054</td>
<td>...</td>
<td>1210</td>
<td>35</td>
<td>4</td>
<td>0.192</td>
<td>20d</td>
<td>31</td>
</tr>
<tr>
<td>16</td>
<td>3/32</td>
<td>0.080</td>
<td>3d</td>
<td>560</td>
<td>36</td>
<td>4 1/4</td>
<td>0.237</td>
<td>30d</td>
<td>24</td>
</tr>
<tr>
<td>17</td>
<td>1/16</td>
<td>0.080</td>
<td>3d</td>
<td>1040</td>
<td>37</td>
<td>5</td>
<td>0.225</td>
<td>40d</td>
<td>18</td>
</tr>
<tr>
<td>18</td>
<td>5/64</td>
<td>0.054</td>
<td>...</td>
<td>470</td>
<td>38</td>
<td>5 1/2</td>
<td>0.244</td>
<td>50d</td>
<td>14</td>
</tr>
<tr>
<td>19</td>
<td>3/32</td>
<td>0.080</td>
<td>4d</td>
<td>320</td>
<td>39</td>
<td>6</td>
<td>0.262</td>
<td>60d</td>
<td>11</td>
</tr>
<tr>
<td>20</td>
<td>1/16</td>
<td>0.099</td>
<td>...</td>
<td>...</td>
<td>40</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

* All dimensions are given in inches.
TABLE 4 Type I, Style 2—Barrel Nails

Note—Steel wire, flat head, diamond point, round smooth shank, bright, zinc or cement coated as specified.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>%9</td>
<td>0.067</td>
<td>0.148</td>
<td>1.550</td>
<td>05</td>
<td>1%</td>
<td>0.076</td>
<td>0.177</td>
<td>670</td>
</tr>
<tr>
<td>02</td>
<td>%4</td>
<td>0.067</td>
<td>0.148</td>
<td>1.300</td>
<td>06</td>
<td>1%</td>
<td>0.080</td>
<td>0.188</td>
<td>540</td>
</tr>
<tr>
<td>03</td>
<td>%2</td>
<td>0.076</td>
<td>0.177</td>
<td>850</td>
<td>07</td>
<td>1%</td>
<td>0.092</td>
<td>0.219</td>
<td>380</td>
</tr>
<tr>
<td>04</td>
<td>1</td>
<td>0.076</td>
<td>0.177</td>
<td>750</td>
<td>08</td>
<td>1%</td>
<td>0.092</td>
<td>0.219</td>
<td>350</td>
</tr>
</tbody>
</table>

* All dimensions are given in inches.

TABLE 5 Type I, Style 3—Boat Nails

Note—Steel wire, oval countersunk head, chisel point, round smooth shank, bright or zinc coated as specified.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>4d</td>
<td>1½</td>
<td>0.188</td>
<td>0.406</td>
<td>82</td>
<td>01</td>
<td>4d</td>
<td>1½</td>
<td>0.250</td>
<td>0.500</td>
<td>47</td>
</tr>
<tr>
<td>02</td>
<td>6d</td>
<td>2</td>
<td>0.188</td>
<td>0.406</td>
<td>62</td>
<td>02</td>
<td>6d</td>
<td>2</td>
<td>0.250</td>
<td>0.500</td>
<td>36</td>
</tr>
<tr>
<td>03</td>
<td>8d</td>
<td>2½</td>
<td>0.188</td>
<td>0.406</td>
<td>50</td>
<td>03</td>
<td>8d</td>
<td>2½</td>
<td>0.250</td>
<td>0.500</td>
<td>29</td>
</tr>
<tr>
<td>04</td>
<td>10d</td>
<td>3</td>
<td>0.250</td>
<td>0.500</td>
<td>24</td>
<td>04</td>
<td>10d</td>
<td>3</td>
<td>0.375</td>
<td>0.750</td>
<td>11</td>
</tr>
<tr>
<td>05</td>
<td>12d</td>
<td>3¾</td>
<td>0.250</td>
<td>0.500</td>
<td>22</td>
<td>05</td>
<td>12d</td>
<td>3¾</td>
<td>0.375</td>
<td>0.750</td>
<td>10</td>
</tr>
<tr>
<td>06</td>
<td>16d</td>
<td>3½</td>
<td>0.250</td>
<td>0.500</td>
<td>20</td>
<td>06</td>
<td>16d</td>
<td>3½</td>
<td>0.375</td>
<td>0.750</td>
<td>9</td>
</tr>
<tr>
<td>07</td>
<td>20d</td>
<td>4</td>
<td>0.250</td>
<td>0.500</td>
<td>18</td>
<td>07</td>
<td>20d</td>
<td>4</td>
<td>0.375</td>
<td>0.750</td>
<td>8</td>
</tr>
</tbody>
</table>

* All dimensions are given in inches.
TABLE 6  Type I, Style 4A—Box Nails

Note—Steel wire, flat head, diamond point, round, barbed or smooth shank, bright or cement coated as specified. When specified, box nails shall have an altered or T-head with a diamond, blunt, or chisel point for use with mechanical drivers.

<table>
<thead>
<tr>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>2d</td>
<td>1</td>
<td>0.067</td>
<td>0.188</td>
</tr>
<tr>
<td>02</td>
<td>3d</td>
<td>1¼</td>
<td>0.076</td>
<td>0.219</td>
</tr>
<tr>
<td>03</td>
<td>4d</td>
<td>1½</td>
<td>0.080</td>
<td>0.219</td>
</tr>
<tr>
<td>04</td>
<td>5d</td>
<td>1⅛</td>
<td>0.080</td>
<td>0.219</td>
</tr>
<tr>
<td>05</td>
<td>6d</td>
<td>2</td>
<td>0.099</td>
<td>0.266</td>
</tr>
<tr>
<td>06</td>
<td>7d</td>
<td>2¼</td>
<td>0.099</td>
<td>0.266</td>
</tr>
<tr>
<td>07</td>
<td>8d</td>
<td>2½</td>
<td>0.113</td>
<td>0.297</td>
</tr>
</tbody>
</table>

All dimensions are given in inches.

TABLE 7  Type I, Style 4B—Box Nails

Note—Steel wire, flat head, diamond point, round smooth shank, cement coated.

<table>
<thead>
<tr>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>2d</td>
<td>1</td>
<td>0.058</td>
<td>0.172</td>
</tr>
<tr>
<td>02</td>
<td>3d</td>
<td>1½</td>
<td>0.052</td>
<td>0.188</td>
</tr>
<tr>
<td>03</td>
<td>4d</td>
<td>1⅛</td>
<td>0.057</td>
<td>0.203</td>
</tr>
<tr>
<td>04</td>
<td>5d</td>
<td>1½</td>
<td>0.072</td>
<td>0.219</td>
</tr>
<tr>
<td>05</td>
<td>6d</td>
<td>1¾</td>
<td>0.086</td>
<td>0.250</td>
</tr>
</tbody>
</table>

All dimensions are given in inches.
### TABLE 8  Type I, Style 5—Broom Nails

Note—Steel wire, flat or star head, diamond point, round smooth shank, bright finish, as specified.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>5/8</td>
<td>0.072</td>
<td>0.203</td>
<td>1480</td>
</tr>
<tr>
<td>02</td>
<td>5/8</td>
<td>0.080</td>
<td>0.219</td>
<td>990</td>
</tr>
<tr>
<td>03</td>
<td>3/4</td>
<td>0.072</td>
<td>0.203</td>
<td>1170</td>
</tr>
<tr>
<td>04</td>
<td>3/4</td>
<td>0.080</td>
<td>0.219</td>
<td>840</td>
</tr>
</tbody>
</table>

* All dimensions are given in inches.

### TABLE 9  Type I, Style 6—Casing Nails

Note—Steel wire, flat countersunk cupped head, diamond point, round smooth shank, bright finish.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>2d</td>
<td>1</td>
<td>0.067</td>
<td>0.999</td>
<td>1090</td>
</tr>
<tr>
<td>02</td>
<td>3d</td>
<td>1⅛</td>
<td>0.076</td>
<td>0.113</td>
<td>650</td>
</tr>
<tr>
<td>03</td>
<td>4d</td>
<td>1⅜</td>
<td>0.080</td>
<td>0.120</td>
<td>490</td>
</tr>
<tr>
<td>04</td>
<td>5d</td>
<td>1¾</td>
<td>0.080</td>
<td>0.120</td>
<td>415</td>
</tr>
<tr>
<td>05</td>
<td>6d</td>
<td>2</td>
<td>0.099</td>
<td>0.142</td>
<td>245</td>
</tr>
<tr>
<td>06</td>
<td>7d</td>
<td>2¼</td>
<td>0.099</td>
<td>0.142</td>
<td>215</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>07</td>
<td>8d</td>
<td>2⅜</td>
<td>0.113</td>
<td>0.155</td>
<td>150</td>
</tr>
<tr>
<td>08</td>
<td>9d</td>
<td>2½</td>
<td>0.113</td>
<td>0.155</td>
<td>135</td>
</tr>
<tr>
<td>09</td>
<td>10d</td>
<td>3</td>
<td>0.128</td>
<td>0.170</td>
<td>95</td>
</tr>
<tr>
<td>10</td>
<td>12d</td>
<td>3¼</td>
<td>0.128</td>
<td>0.170</td>
<td>90</td>
</tr>
<tr>
<td>11</td>
<td>16d</td>
<td>3½</td>
<td>0.135</td>
<td>0.177</td>
<td>75</td>
</tr>
</tbody>
</table>

* All dimensions are given in inches.
### TABLE 10 Type I, Style 7—Cooler Nails\(^A\)

Note—Steel wire, flat head, diamond point, round smooth shank, cement coated. When specified, coolers shall have an altered or T-head for use with mechanical drivers.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>2d</td>
<td>1</td>
<td>0.062</td>
<td>0.172</td>
<td>1110</td>
<td>06</td>
<td>7d</td>
<td>2(\frac{1}{4})</td>
<td>0.099</td>
<td>0.266</td>
<td>210</td>
</tr>
<tr>
<td>02</td>
<td>3d</td>
<td>1(\frac{1}{8})</td>
<td>0.067</td>
<td>0.188</td>
<td>840</td>
<td>07</td>
<td>8d</td>
<td>2(\frac{1}{4})</td>
<td>0.113</td>
<td>0.281</td>
<td>140</td>
</tr>
<tr>
<td>03</td>
<td>4d</td>
<td>1(\frac{1}{8})</td>
<td>0.080</td>
<td>0.219</td>
<td>490</td>
<td>08</td>
<td>9d</td>
<td>2(\frac{1}{4})</td>
<td>0.113</td>
<td>0.281</td>
<td>130</td>
</tr>
<tr>
<td>04</td>
<td>5d</td>
<td>1(\frac{1}{8})</td>
<td>0.086</td>
<td>0.234</td>
<td>370</td>
<td>09</td>
<td>10d</td>
<td>2(\frac{1}{4})</td>
<td>0.120</td>
<td>0.297</td>
<td>100</td>
</tr>
<tr>
<td>05</td>
<td>6d</td>
<td>1(\frac{1}{8})</td>
<td>0.092</td>
<td>0.250</td>
<td>280</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

\(^A\) All dimensions are given in inches.

### TABLE 11 Type I, Style 8—Sinker Nails\(^A\)

Note—Steel wire, flat countersunk head, diamond point, round smooth shank, bright or cement coated. When specified, sinkers shall have an altered or T-head for use with mechanical drivers.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>3d</td>
<td>1(\frac{1}{8})</td>
<td>0.067</td>
<td>0.172</td>
<td>940</td>
<td>08</td>
<td>12d</td>
<td>3(\frac{1}{4})</td>
<td>0.135</td>
<td>0.312</td>
<td>81</td>
</tr>
<tr>
<td>02</td>
<td>4d</td>
<td>1(\frac{1}{8})</td>
<td>0.080</td>
<td>0.203</td>
<td>530</td>
<td>09</td>
<td>16d</td>
<td>3(\frac{1}{4})</td>
<td>0.148</td>
<td>0.344</td>
<td>64</td>
</tr>
<tr>
<td>03</td>
<td>5d</td>
<td>1(\frac{1}{8})</td>
<td>0.085</td>
<td>0.219</td>
<td>390</td>
<td>10</td>
<td>20d</td>
<td>3(\frac{1}{4})</td>
<td>0.177</td>
<td>0.375</td>
<td>40</td>
</tr>
<tr>
<td>04</td>
<td>6d</td>
<td>1(\frac{1}{8})</td>
<td>0.092</td>
<td>0.234</td>
<td>290</td>
<td>11</td>
<td>30d</td>
<td>4(\frac{1}{4})</td>
<td>0.192</td>
<td>0.406</td>
<td>30</td>
</tr>
<tr>
<td>05</td>
<td>7d</td>
<td>2(\frac{1}{4})</td>
<td>0.099</td>
<td>0.250</td>
<td>220</td>
<td>12</td>
<td>40d</td>
<td>4(\frac{1}{4})</td>
<td>0.207</td>
<td>0.438</td>
<td>23</td>
</tr>
<tr>
<td>06</td>
<td>8d</td>
<td>2(\frac{1}{4})</td>
<td>0.113</td>
<td>0.266</td>
<td>150</td>
<td>13</td>
<td>60d</td>
<td>5(\frac{1}{4})</td>
<td>0.244</td>
<td>0.500</td>
<td>14</td>
</tr>
<tr>
<td>07</td>
<td>10d</td>
<td>2(\frac{1}{4})</td>
<td>0.120</td>
<td>0.281</td>
<td>110</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

\(^A\) All dimensions are given in inches.
TABLE 12  Type I, Style 9—Corker Nails

Note—Steel wire, flat countersunk head, diamond point, round smooth shank, cement coated. When specified, corkers shall have an altered or T-head for use with mechanical drivers.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>2d</td>
<td>1</td>
<td>0.062</td>
<td>0.156</td>
<td>1220</td>
<td>09</td>
<td>10d</td>
<td>2 ½</td>
<td>0.135</td>
<td>0.312</td>
<td>89</td>
</tr>
<tr>
<td>02</td>
<td>3d</td>
<td>1⅛</td>
<td>0.072</td>
<td>0.188</td>
<td>720</td>
<td>10</td>
<td>12d</td>
<td>3 ½</td>
<td>0.135</td>
<td>0.312</td>
<td>61</td>
</tr>
<tr>
<td>03</td>
<td>4d</td>
<td>1⅔</td>
<td>0.086</td>
<td>0.219</td>
<td>420</td>
<td>11</td>
<td>16d</td>
<td>3 ½</td>
<td>0.148</td>
<td>0.344</td>
<td>62</td>
</tr>
<tr>
<td>04</td>
<td>5d</td>
<td>1⅜</td>
<td>0.086</td>
<td>0.219</td>
<td>320</td>
<td>12</td>
<td>20d</td>
<td>3 ½</td>
<td>0.177</td>
<td>0.375</td>
<td>38</td>
</tr>
<tr>
<td>05</td>
<td>6d</td>
<td>1⅝</td>
<td>0.099</td>
<td>0.260</td>
<td>250</td>
<td>13</td>
<td>25d</td>
<td>4 ½</td>
<td>0.192</td>
<td>0.406</td>
<td>29</td>
</tr>
<tr>
<td>06</td>
<td>7d</td>
<td>2⅛</td>
<td>0.099</td>
<td>0.250</td>
<td>220</td>
<td>14</td>
<td>30d</td>
<td>4 ½</td>
<td>0.207</td>
<td>0.438</td>
<td>22</td>
</tr>
<tr>
<td>07</td>
<td>8d</td>
<td>2 ½</td>
<td>0.120</td>
<td>0.281</td>
<td>130</td>
<td>15</td>
<td>35d</td>
<td>5 ½</td>
<td>0.226</td>
<td>0.468</td>
<td>17</td>
</tr>
<tr>
<td>08</td>
<td>9d</td>
<td>2⅛</td>
<td>0.120</td>
<td>0.281</td>
<td>120</td>
<td>16</td>
<td>40d</td>
<td>5 ½</td>
<td>0.244</td>
<td>0.500</td>
<td>13</td>
</tr>
</tbody>
</table>

* All dimensions are given in inches.

TABLE 13  Type I, Style 10—Common Nails

Note—Aluminum alloy wire, flat head, diamond point, round smooth shank, or, when specified, square barbed shank.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>4d</td>
<td>1⅝</td>
<td>0.099</td>
<td>0.250</td>
<td>830</td>
<td>04</td>
<td>10d</td>
<td>3</td>
<td>0.162</td>
<td>0.312</td>
<td>170</td>
</tr>
<tr>
<td>02</td>
<td>6d</td>
<td>2</td>
<td>0.120</td>
<td>0.266</td>
<td>430</td>
<td>05</td>
<td>16d</td>
<td>3 ½</td>
<td>0.177</td>
<td>0.344</td>
<td>120</td>
</tr>
<tr>
<td>03</td>
<td>8d</td>
<td>2 ½</td>
<td>0.148</td>
<td>0.281</td>
<td>220</td>
<td>06</td>
<td>20d</td>
<td>4</td>
<td>0.199</td>
<td>0.406</td>
<td>78</td>
</tr>
</tbody>
</table>

* All dimensions are given in inches.
### TABLE 14 Type I, Style 10—Common Nails

Note—Copper wire, flat head, diamond point, round smooth shank.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>½</td>
<td>0.065</td>
<td>0.156</td>
<td>1380</td>
<td>10</td>
<td>2</td>
<td>0.120</td>
<td>0.266</td>
<td>130</td>
</tr>
<tr>
<td>02</td>
<td>¾</td>
<td>0.065</td>
<td>0.156</td>
<td>1160</td>
<td>11</td>
<td>2</td>
<td>0.134</td>
<td>0.281</td>
<td>83</td>
</tr>
<tr>
<td>03</td>
<td>½</td>
<td>0.072</td>
<td>0.172</td>
<td>960</td>
<td>12</td>
<td>2½</td>
<td>0.134</td>
<td>0.281</td>
<td>86</td>
</tr>
<tr>
<td>04</td>
<td>¾</td>
<td>0.072</td>
<td>0.172</td>
<td>810</td>
<td>13</td>
<td>3</td>
<td>0.148</td>
<td>0.312</td>
<td>56</td>
</tr>
<tr>
<td>05</td>
<td>1</td>
<td>0.072</td>
<td>0.172</td>
<td>700</td>
<td>14</td>
<td>3½</td>
<td>0.165</td>
<td>0.344</td>
<td>40</td>
</tr>
<tr>
<td>06</td>
<td>1½</td>
<td>0.083</td>
<td>0.203</td>
<td>420</td>
<td>15</td>
<td>4</td>
<td>0.203</td>
<td>0.406</td>
<td>23</td>
</tr>
<tr>
<td>07</td>
<td>1</td>
<td>0.109</td>
<td>0.250</td>
<td>210</td>
<td>16</td>
<td>4½</td>
<td>0.220</td>
<td>0.438</td>
<td>18</td>
</tr>
<tr>
<td>08</td>
<td>1½</td>
<td>0.109</td>
<td>0.250</td>
<td>180</td>
<td>17</td>
<td>5</td>
<td>0.238</td>
<td>0.469</td>
<td>14</td>
</tr>
<tr>
<td>09</td>
<td>1</td>
<td>0.120</td>
<td>0.266</td>
<td>140</td>
<td>18</td>
<td>6</td>
<td>0.284</td>
<td>0.531</td>
<td>8</td>
</tr>
</tbody>
</table>

*All dimensions are given in inches.

### TABLE 15 Type I, Style 10—Common Nails

Note—Steel wire, flat head, diamond point, round smooth shank, bright, zinc or cement coated as specified.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>2d</td>
<td>1</td>
<td>0.072</td>
<td>0.172</td>
<td>850</td>
</tr>
<tr>
<td>02</td>
<td>3d</td>
<td>1½</td>
<td>0.080</td>
<td>0.203</td>
<td>540</td>
</tr>
<tr>
<td>03</td>
<td>4d</td>
<td>1½</td>
<td>0.099</td>
<td>0.250</td>
<td>290</td>
</tr>
<tr>
<td>04</td>
<td>5d</td>
<td>1½</td>
<td>0.099</td>
<td>0.250</td>
<td>250</td>
</tr>
<tr>
<td>05</td>
<td>6d</td>
<td>2</td>
<td>0.113</td>
<td>0.266</td>
<td>170</td>
</tr>
<tr>
<td>06</td>
<td>7d</td>
<td>2½</td>
<td>0.113</td>
<td>0.266</td>
<td>150</td>
</tr>
<tr>
<td>07</td>
<td>8d</td>
<td>2½</td>
<td>0.131</td>
<td>0.281</td>
<td>100</td>
</tr>
<tr>
<td>08</td>
<td>9d</td>
<td>2¼</td>
<td>0.131</td>
<td>0.281</td>
<td>92</td>
</tr>
</tbody>
</table>

*All dimensions are given in inches.
Note—Aluminum alloy wire, or steel wire, (bright, zinc coated or cement coated), altered or T-head, diamond or chisel point, round smooth shank, as specified. For use with mechanical drivers.

---

<table>
<thead>
<tr>
<th>F 1667 NL COMM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dash No.</strong></td>
</tr>
<tr>
<td>01</td>
</tr>
<tr>
<td>02</td>
</tr>
<tr>
<td>03</td>
</tr>
<tr>
<td>04</td>
</tr>
<tr>
<td>05</td>
</tr>
<tr>
<td>06</td>
</tr>
<tr>
<td>07</td>
</tr>
<tr>
<td>08</td>
</tr>
<tr>
<td>09</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>11</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>13</td>
</tr>
<tr>
<td>14</td>
</tr>
</tbody>
</table>

---

*TABLE 16 Type I, Style 10—Common Nails*
TABLE 17 Type I, Style 11—Concrete Nails

Note—Hardened steel, flat countersunk head, diamond point, smooth or mechanically deformed shank formed from round or square stock, as specified, bright finish.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>½</td>
<td>0.148</td>
<td>0.312</td>
<td>450</td>
</tr>
<tr>
<td>02</td>
<td>¾</td>
<td>0.148</td>
<td>0.312</td>
<td>350</td>
</tr>
<tr>
<td>03</td>
<td>¾</td>
<td>0.148</td>
<td>0.312</td>
<td>250</td>
</tr>
<tr>
<td>04</td>
<td>¾</td>
<td>0.148</td>
<td>0.312</td>
<td>250</td>
</tr>
<tr>
<td>05</td>
<td>1</td>
<td>0.148</td>
<td>0.312</td>
<td>210</td>
</tr>
</tbody>
</table>

TABLE 18 Type I, Style 12—Double-Headed Nails

Note—Steel wire, flat heads, diamond point, round smooth shank, bright finish or cement coated.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>¾</td>
<td>0.181</td>
<td>0.284</td>
<td>240</td>
</tr>
<tr>
<td>02</td>
<td>1</td>
<td>0.181</td>
<td>0.284</td>
<td>204</td>
</tr>
<tr>
<td>03</td>
<td>1¼</td>
<td>0.181</td>
<td>0.284</td>
<td>116</td>
</tr>
<tr>
<td>04</td>
<td>1½</td>
<td>0.181</td>
<td>0.284</td>
<td>112</td>
</tr>
</tbody>
</table>

^ All dimensions are given in inches.
TABLE 19 Type I, Style 13—Fine Nails

Note—Steel or copper wire, flat head, diamond point, round smooth shank, bright finish.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>3d</td>
<td>1(\frac{1}{4})</td>
<td>0.072</td>
<td>0.172</td>
<td>760</td>
</tr>
</tbody>
</table>

\(^{A}\) All dimensions are given in inches.

TABLE 20 Type I, Style 14—Finish Nails

Note—Steel wire, brad head, altered or clipped T-head for use with mechanical drivers, diamond or chisel point, smooth or barbed shank formed from round or square stock, as specified, bright finished.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>2d</td>
<td>1</td>
<td>0.058</td>
<td>0.086</td>
<td>1.470</td>
</tr>
<tr>
<td>02</td>
<td>3d</td>
<td>1(\frac{3}{4})</td>
<td>0.067</td>
<td>0.099</td>
<td>0.800</td>
</tr>
<tr>
<td>03</td>
<td>4d</td>
<td>1(\frac{1}{2})</td>
<td>0.072</td>
<td>0.106</td>
<td>0.630</td>
</tr>
<tr>
<td>04</td>
<td>5d</td>
<td>1(\frac{3}{4})</td>
<td>0.072</td>
<td>0.106</td>
<td>0.530</td>
</tr>
<tr>
<td>05</td>
<td>6d</td>
<td>2</td>
<td>0.092</td>
<td>0.135</td>
<td>0.290</td>
</tr>
<tr>
<td>06</td>
<td>7d</td>
<td>2(\frac{1}{4})</td>
<td>0.092</td>
<td>0.135</td>
<td>0.250</td>
</tr>
<tr>
<td>07</td>
<td>8d</td>
<td>2(\frac{1}{2})</td>
<td>0.099</td>
<td>0.142</td>
<td>0.190</td>
</tr>
<tr>
<td>08</td>
<td>9d</td>
<td>2(\frac{3}{4})</td>
<td>0.099</td>
<td>0.142</td>
<td>0.180</td>
</tr>
<tr>
<td>09</td>
<td>10d</td>
<td>3</td>
<td>0.113</td>
<td>0.155</td>
<td>0.120</td>
</tr>
<tr>
<td>10</td>
<td>12d</td>
<td>3(\frac{1}{4})</td>
<td>0.113</td>
<td>0.155</td>
<td>0.110</td>
</tr>
<tr>
<td>11</td>
<td>16d</td>
<td>3(\frac{1}{2})</td>
<td>0.120</td>
<td>0.162</td>
<td>0.093</td>
</tr>
<tr>
<td>12</td>
<td>20d</td>
<td>4</td>
<td>0.135</td>
<td>0.177</td>
<td>0.065</td>
</tr>
</tbody>
</table>

\(^{A}\) All dimensions are given in inches.
TABLE 21 Type I, Style 15—Flooring Nails

NOTE—Hardened steel or steel wire, casing head or flat-cupped countersunk head, diamond or blunt point, round, smooth or mechanically deformed shank, dark (hardened), bright (steel wire) or cement coated, as specified.

- Identifies a flooring nail with a length of 3¼, a diameter of 0.148, a head diameter of 0.281, and a bright finish.
- S = smooth
- D = deformed
- B = bright
- C = cement coated
- D = dark (hardened)

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>2d</td>
<td>1</td>
<td>0.072</td>
<td>0.141</td>
<td>840</td>
</tr>
<tr>
<td>02</td>
<td>3d</td>
<td>⅝</td>
<td>0.072</td>
<td>0.141</td>
<td>700</td>
</tr>
<tr>
<td>03</td>
<td>4d</td>
<td>1½</td>
<td>0.080</td>
<td>0.156</td>
<td>430</td>
</tr>
<tr>
<td>04</td>
<td>4d</td>
<td>1½</td>
<td>0.092</td>
<td>0.156</td>
<td>370</td>
</tr>
<tr>
<td>05</td>
<td>5d</td>
<td>1¾</td>
<td>0.092</td>
<td>0.156</td>
<td>310</td>
</tr>
<tr>
<td>06</td>
<td>5d</td>
<td>2</td>
<td>0.113</td>
<td>0.203</td>
<td>180</td>
</tr>
</tbody>
</table>

TABLE 22 Type I, Style 16—Lath Nails

NOTE—Steel wire, flat head, diamond point, round smooth shank, blued finish.

- Identifies a lath nail with a flat head, a length of 1½, a diameter of 0.072, and a head diameter of 0.172.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>2d</td>
<td>1</td>
<td>0.058</td>
<td>0.141</td>
<td>1.280</td>
</tr>
<tr>
<td>02</td>
<td>3d</td>
<td>1½</td>
<td>0.062</td>
<td>0.156</td>
<td>0.980</td>
</tr>
<tr>
<td>03</td>
<td>3d</td>
<td>1½</td>
<td>0.072</td>
<td>0.172</td>
<td>0.760</td>
</tr>
</tbody>
</table>

**All dimensions are given in inches.**
TABLE 23  Type I, Style 16—Lath Nails

Note—Steel wire, flat hook-head, diamond point, round smooth shank, bright, blued, or zinc coated as specified.

<table>
<thead>
<tr>
<th>F 1667 NLLHH</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dash No.</td>
<td>L</td>
<td>D</td>
<td>H</td>
<td>No./lb</td>
</tr>
<tr>
<td>01</td>
<td>1 ½</td>
<td>0.106</td>
<td>0.438</td>
<td>280</td>
</tr>
</tbody>
</table>

^ All dimensions are given in inches.
TABLE 24 Type I, Style 17—Masonry Nails

Note—Hardened steel, flat or flat countersunk head, diamond point, mechanically deformed shank, bright finish.

- Identifies a standard masonry nail with a length of \( \frac{3}{4} \), a diameter 0.148, and a head diameter of 0.312.
- \( S \) = standard
- \( H \) = heavy

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>( L )</th>
<th>( D )</th>
<th>( H )</th>
<th>No./lb</th>
<th>Dash No.</th>
<th>( L )</th>
<th>( D )</th>
<th>( H )</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>( \frac{3}{8} )</td>
<td>0.148</td>
<td>0.312</td>
<td>340</td>
<td>09</td>
<td>2( \frac{3}{4} )</td>
<td>0.148</td>
<td>0.312</td>
<td>76</td>
</tr>
<tr>
<td>02</td>
<td>( \frac{3}{4} )</td>
<td>0.148</td>
<td>0.312</td>
<td>280</td>
<td>10</td>
<td>2( \frac{3}{4} )</td>
<td>0.148</td>
<td>0.312</td>
<td>70</td>
</tr>
<tr>
<td>03</td>
<td>1</td>
<td>0.148</td>
<td>0.312</td>
<td>170</td>
<td>11</td>
<td>3</td>
<td>0.148</td>
<td>0.312</td>
<td>67</td>
</tr>
<tr>
<td>04</td>
<td>1( \frac{1}{4} )</td>
<td>0.148</td>
<td>0.312</td>
<td>12</td>
<td>12</td>
<td>3( \frac{1}{4} )</td>
<td>0.148</td>
<td>0.312</td>
<td>60</td>
</tr>
<tr>
<td>05</td>
<td>1( \frac{1}{2} )</td>
<td>0.148</td>
<td>0.312</td>
<td>130</td>
<td>13</td>
<td>3( \frac{1}{2} )</td>
<td>0.162</td>
<td>0.344</td>
<td>48</td>
</tr>
<tr>
<td>06</td>
<td>1( \frac{3}{4} )</td>
<td>0.148</td>
<td>0.312</td>
<td>110</td>
<td>14</td>
<td>3( \frac{3}{4} )</td>
<td>0.162</td>
<td>0.344</td>
<td>45</td>
</tr>
<tr>
<td>07</td>
<td>2</td>
<td>0.148</td>
<td>0.312</td>
<td>98</td>
<td>15</td>
<td>4</td>
<td>0.177</td>
<td>0.375</td>
<td>35</td>
</tr>
<tr>
<td>08</td>
<td>2( \frac{1}{4} )</td>
<td>0.148</td>
<td>0.312</td>
<td>84</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>( L )</th>
<th>( D )</th>
<th>( H )</th>
<th>No./lb</th>
<th>Dash No.</th>
<th>( L )</th>
<th>( D )</th>
<th>( H )</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1</td>
<td>0.250</td>
<td>0.562</td>
<td>63</td>
<td>05</td>
<td>2</td>
<td>0.250</td>
<td>0.562</td>
<td>34</td>
</tr>
<tr>
<td>02</td>
<td>1( \frac{1}{4} )</td>
<td>0.250</td>
<td>0.562</td>
<td>47</td>
<td>06</td>
<td>2( \frac{3}{4} )</td>
<td>0.250</td>
<td>0.562</td>
<td>27</td>
</tr>
<tr>
<td>03</td>
<td>1( \frac{1}{2} )</td>
<td>0.250</td>
<td>0.562</td>
<td>43</td>
<td>07</td>
<td>3( \frac{1}{4} )</td>
<td>0.250</td>
<td>0.562</td>
<td>19</td>
</tr>
<tr>
<td>04</td>
<td>1( \frac{3}{4} )</td>
<td>0.250</td>
<td>0.562</td>
<td>39</td>
<td>08</td>
<td>3</td>
<td>0.250</td>
<td>0.562</td>
<td>24</td>
</tr>
</tbody>
</table>

* All dimensions are given in inches.
TABLE 25 Type I, Style 18—Pallet Nails

Note—Hardened steel or steel wire (for mechanical drivers), flat head, altered or T-Head (for mechanical drivers), diamond point, round, mechanically deformed shank, bright finish (steel wire), or dark (hardened), as specified.

- Identifies a pallet nail with a length of 4, a head diameter of 0.438, and dark (hardened).
  - B = bright
  - D = dark (hardened)

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1(\frac{1}{2})</td>
<td>0.120</td>
<td>0.281</td>
<td>190</td>
</tr>
<tr>
<td>02</td>
<td>1(\frac{3}{4})</td>
<td>0.120</td>
<td>0.281</td>
<td>170</td>
</tr>
<tr>
<td>03</td>
<td>2</td>
<td>0.120</td>
<td>0.281</td>
<td>140</td>
</tr>
<tr>
<td>04</td>
<td>2(\frac{1}{4})</td>
<td>0.120</td>
<td>0.281</td>
<td>130</td>
</tr>
<tr>
<td>05</td>
<td>2(\frac{1}{2})</td>
<td>0.120</td>
<td>0.281</td>
<td>120</td>
</tr>
<tr>
<td>06</td>
<td>3</td>
<td>0.120</td>
<td>0.312</td>
<td>93</td>
</tr>
<tr>
<td>07</td>
<td>3(\frac{1}{2})</td>
<td>0.135</td>
<td>0.312</td>
<td>98</td>
</tr>
<tr>
<td>08</td>
<td>3(\frac{1}{4})</td>
<td>0.135</td>
<td>0.312</td>
<td>79</td>
</tr>
<tr>
<td>09</td>
<td>3(\frac{3}{4})</td>
<td>0.148</td>
<td>0.312</td>
<td>66</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>0.155</td>
<td>0.312</td>
<td>73</td>
</tr>
</tbody>
</table>

* All dimensions are given in inches.

TABLE 26 Type I, Style 19—Gypsum-Wallboard, Gypsumboard, and Drywall Nails

Note—Steel wire, flat head, diamond point, round smooth or deformed shank, bright or blued finish.

- Identifies a gypsum-wallboard nail with a smooth shank, a length of 1\(\frac{1}{8}\), a diameter of 0.092, a head diameter of 0.375, and blued.
  - S = smooth shank
  - M = deformed shank
  - B = bright
  - F = blued

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1(\frac{1}{8})</td>
<td>0.092</td>
<td>0.297</td>
<td>470</td>
</tr>
<tr>
<td>02</td>
<td>1(\frac{1}{4})</td>
<td>0.092</td>
<td>0.375</td>
<td>450</td>
</tr>
<tr>
<td>03</td>
<td>1(\frac{1}{4})</td>
<td>0.092</td>
<td>0.297</td>
<td>420</td>
</tr>
<tr>
<td>04</td>
<td>1(\frac{1}{8})</td>
<td>0.106</td>
<td>0.375</td>
<td>310</td>
</tr>
<tr>
<td>05</td>
<td>1(\frac{3}{4})</td>
<td>0.092</td>
<td>0.375</td>
<td>290</td>
</tr>
</tbody>
</table>

* All dimensions are given in inches.
### TABLE 27 Type I, Style 19—Gypsum-Wallboard, Gypsumboard, and Drywall Nails

*Note—Steel wire, flat slightly countersunk head, long diamond point, round mechanically deformed shank, bright or blued finish.*

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1½</td>
<td>0.099</td>
<td>0.250</td>
<td>380</td>
</tr>
<tr>
<td>02</td>
<td>1¼</td>
<td>0.099</td>
<td>0.250</td>
<td>340</td>
</tr>
<tr>
<td>03</td>
<td>1³⁄₄</td>
<td>0.099</td>
<td>0.250</td>
<td>320</td>
</tr>
<tr>
<td>04</td>
<td>1½</td>
<td>0.099</td>
<td>0.250</td>
<td>290</td>
</tr>
<tr>
<td>05</td>
<td>1¾</td>
<td>0.099</td>
<td>0.250</td>
<td>270</td>
</tr>
</tbody>
</table>

*All dimensions are given in inches.

---

### TABLE 28 Type I, Style 20—Roofing Nails

*Note—Aluminum alloy wire, flat head, diamond point, round smooth shank, or, when specified, square-barbed shank.*

- Identifies an aluminum roofing nail with a barbed shank, a length of 1, a diameter of 0.120, a head diameter of 0.438.
- S = smooth shank
- Q = barbed shank

<table>
<thead>
<tr>
<th>F 1667 NL.RFA</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>3/16</td>
<td>0.120</td>
<td>0.438</td>
<td>940</td>
</tr>
<tr>
<td>02</td>
<td>3/16</td>
<td>0.135</td>
<td>0.438</td>
<td>750</td>
</tr>
<tr>
<td>03</td>
<td>3/16</td>
<td>0.120</td>
<td>0.438</td>
<td>830</td>
</tr>
<tr>
<td>04</td>
<td>3/16</td>
<td>0.135</td>
<td>0.438</td>
<td>660</td>
</tr>
<tr>
<td>05</td>
<td>1</td>
<td>0.120</td>
<td>0.438</td>
<td>700</td>
</tr>
<tr>
<td>06</td>
<td>1</td>
<td>0.135</td>
<td>0.438</td>
<td>600</td>
</tr>
<tr>
<td>07</td>
<td>1</td>
<td>0.135</td>
<td>0.438</td>
<td>580</td>
</tr>
</tbody>
</table>

*All dimensions are given in inches.*
TABLE 29 Type I, Style 20—Roofing Nails\(^A\)

Note—Steel wire, flat head, diamond point, round, smooth or barbed shank, bright or zinc coated, as specified, for hand driving or for use with mechanical drivers.

Identifies a steel roofing nail with a barbed shank, a length of 1 ¼ inches, a diameter of 0.142 inches, a head diameter of 0.484 inches, and a bright finish.

- S = smooth shank
- Q = barbed shank
- B = bright
- Z = zinc coated

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>½</td>
<td>0.106</td>
<td>0.375</td>
<td>460</td>
<td>29</td>
<td>¼</td>
<td>0.120</td>
<td>0.312</td>
<td>240</td>
</tr>
<tr>
<td>02</td>
<td>¼</td>
<td>0.120</td>
<td>0.438</td>
<td>340</td>
<td>30</td>
<td>¼</td>
<td>0.120</td>
<td>0.438</td>
<td>220</td>
</tr>
<tr>
<td>03</td>
<td>¼</td>
<td>0.135</td>
<td>0.469</td>
<td>270</td>
<td>31</td>
<td>¼</td>
<td>0.120</td>
<td>0.500</td>
<td>...</td>
</tr>
<tr>
<td>04</td>
<td>¼</td>
<td>0.142</td>
<td>0.484</td>
<td>240</td>
<td>32</td>
<td>¼</td>
<td>0.135</td>
<td>0.469</td>
<td>180</td>
</tr>
<tr>
<td>05</td>
<td>¼</td>
<td>0.148</td>
<td>0.500</td>
<td>220</td>
<td>33</td>
<td>¼</td>
<td>0.142</td>
<td>0.484</td>
<td>160</td>
</tr>
<tr>
<td>06</td>
<td>¼</td>
<td>0.162</td>
<td>0.500</td>
<td>200</td>
<td>34</td>
<td>¼</td>
<td>0.148</td>
<td>0.500</td>
<td>140</td>
</tr>
<tr>
<td>07</td>
<td>⅛</td>
<td>0.106</td>
<td>0.375</td>
<td>...</td>
<td>35</td>
<td>⅛</td>
<td>0.162</td>
<td>0.500</td>
<td>120</td>
</tr>
<tr>
<td>08</td>
<td>⅛</td>
<td>0.120</td>
<td>0.438</td>
<td>300</td>
<td>36</td>
<td>⅛</td>
<td>0.106</td>
<td>0.375</td>
<td>...</td>
</tr>
<tr>
<td>09</td>
<td>⅛</td>
<td>0.120</td>
<td>0.500</td>
<td>250</td>
<td>37</td>
<td>⅛</td>
<td>0.120</td>
<td>0.438</td>
<td>180</td>
</tr>
<tr>
<td>10</td>
<td>⅛</td>
<td>0.135</td>
<td>0.469</td>
<td>240</td>
<td>38</td>
<td>⅛</td>
<td>0.120</td>
<td>0.500</td>
<td>160</td>
</tr>
<tr>
<td>11</td>
<td>⅛</td>
<td>0.142</td>
<td>0.484</td>
<td>210</td>
<td>39</td>
<td>⅛</td>
<td>0.135</td>
<td>0.469</td>
<td>150</td>
</tr>
<tr>
<td>12</td>
<td>⅛</td>
<td>0.148</td>
<td>0.500</td>
<td>190</td>
<td>40</td>
<td>⅛</td>
<td>0.142</td>
<td>0.484</td>
<td>130</td>
</tr>
<tr>
<td>13</td>
<td>⅛</td>
<td>0.162</td>
<td>0.500</td>
<td>170</td>
<td>41</td>
<td>⅛</td>
<td>0.148</td>
<td>0.500</td>
<td>120</td>
</tr>
<tr>
<td>14</td>
<td>1</td>
<td>0.106</td>
<td>0.375</td>
<td>360</td>
<td>42</td>
<td>1</td>
<td>0.162</td>
<td>0.500</td>
<td>110</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>0.106</td>
<td>0.375</td>
<td>360</td>
<td>43</td>
<td>1</td>
<td>0.106</td>
<td>0.375</td>
<td>220</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>0.120</td>
<td>0.438</td>
<td>270</td>
<td>44</td>
<td>1</td>
<td>0.120</td>
<td>0.438</td>
<td>180</td>
</tr>
<tr>
<td>17</td>
<td>1</td>
<td>0.120</td>
<td>0.500</td>
<td>220</td>
<td>45</td>
<td>1</td>
<td>0.120</td>
<td>0.500</td>
<td>140</td>
</tr>
<tr>
<td>18</td>
<td>1</td>
<td>0.135</td>
<td>0.469</td>
<td>210</td>
<td>46</td>
<td>1</td>
<td>0.135</td>
<td>0.469</td>
<td>130</td>
</tr>
<tr>
<td>19</td>
<td>1</td>
<td>0.142</td>
<td>0.484</td>
<td>190</td>
<td>47</td>
<td>1</td>
<td>0.142</td>
<td>0.484</td>
<td>120</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
<td>0.148</td>
<td>0.500</td>
<td>170</td>
<td>48</td>
<td>1</td>
<td>0.148</td>
<td>0.500</td>
<td>110</td>
</tr>
<tr>
<td>21</td>
<td>1</td>
<td>0.162</td>
<td>0.500</td>
<td>150</td>
<td>49</td>
<td>1</td>
<td>0.162</td>
<td>0.500</td>
<td>92</td>
</tr>
<tr>
<td>22</td>
<td>1¼</td>
<td>0.106</td>
<td>0.375</td>
<td>320</td>
<td>50</td>
<td>1¼</td>
<td>0.120</td>
<td>0.375</td>
<td>290</td>
</tr>
<tr>
<td>23</td>
<td>1¼</td>
<td>0.120</td>
<td>0.438</td>
<td>240</td>
<td>51</td>
<td>1¼</td>
<td>0.120</td>
<td>0.375</td>
<td>220</td>
</tr>
<tr>
<td>24</td>
<td>1¼</td>
<td>0.135</td>
<td>0.469</td>
<td>190</td>
<td>52</td>
<td>1¼</td>
<td>0.120</td>
<td>0.375</td>
<td>232</td>
</tr>
<tr>
<td>25</td>
<td>1¼</td>
<td>0.142</td>
<td>0.484</td>
<td>170</td>
<td>53</td>
<td>1¼</td>
<td>0.120</td>
<td>0.375</td>
<td>209</td>
</tr>
<tr>
<td>26</td>
<td>1¼</td>
<td>0.148</td>
<td>0.500</td>
<td>160</td>
<td>54</td>
<td>1¼</td>
<td>0.120</td>
<td>0.375</td>
<td>179</td>
</tr>
<tr>
<td>27</td>
<td>1¼</td>
<td>0.162</td>
<td>0.500</td>
<td>140</td>
<td>55</td>
<td>1¼</td>
<td>0.120</td>
<td>0.375</td>
<td>157</td>
</tr>
<tr>
<td>28</td>
<td>1¼</td>
<td>0.162</td>
<td>0.375</td>
<td>300</td>
<td></td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

\(^A\) All dimensions are given in inches.
TABLE 30 Type I, Style 20—Roofing Nails

Note—Copper-clad wire, flat head, diamond point, round smooth shank.

```
<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>2d</td>
<td>1</td>
<td>0.120</td>
<td>0.375</td>
<td>280</td>
</tr>
<tr>
<td>02</td>
<td>3d</td>
<td>1¼</td>
<td>0.120</td>
<td>0.375</td>
<td>220</td>
</tr>
<tr>
<td>03</td>
<td>4d</td>
<td>1½</td>
<td>0.120</td>
<td>0.375</td>
<td>190</td>
</tr>
<tr>
<td>04</td>
<td>5d</td>
<td>1¼</td>
<td>0.120</td>
<td>0.375</td>
<td>160</td>
</tr>
<tr>
<td>05</td>
<td>6d</td>
<td>2</td>
<td>0.120</td>
<td>0.375</td>
<td>140</td>
</tr>
<tr>
<td>06</td>
<td>7d</td>
<td>2¼</td>
<td>0.120</td>
<td>0.375</td>
<td>130</td>
</tr>
</tbody>
</table>
```

ASTM identifier: F 1667 NLRFC

^ All dimensions are given in inches.

TABLE 31 Type I, Style 20—Roofing Nails

Note—Steel wire, leak-resistant convex head, diamond point, round smooth shank, zinc coated.

```
<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1¼</td>
<td>0.135</td>
<td>0.500</td>
<td>110</td>
</tr>
<tr>
<td>02</td>
<td>2</td>
<td>0.135</td>
<td>0.500</td>
<td>98</td>
</tr>
</tbody>
</table>
```

ASTM identifier: F 1667 NLRFL

^ All dimensions are given in inches.
TABLE 32  Type I, Style 20—Roofing Nails

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>⅛</td>
<td>0.106</td>
<td>0.625</td>
<td>190</td>
</tr>
<tr>
<td>02</td>
<td>3/₄</td>
<td>0.120</td>
<td>0.625</td>
<td>170</td>
</tr>
<tr>
<td>03</td>
<td>⅜</td>
<td>0.106</td>
<td>0.625</td>
<td>180</td>
</tr>
<tr>
<td>04</td>
<td>¾</td>
<td>0.120</td>
<td>0.625</td>
<td>160</td>
</tr>
<tr>
<td>05</td>
<td>1</td>
<td>0.106</td>
<td>0.625</td>
<td>170</td>
</tr>
</tbody>
</table>

Note—Steel wire, flat reinforced head, needle or diamond point, round smooth Shank, bright or zinc coated, as specified. (For prepared felt roofing.)

---

TABLE 33  Type I, Style 20—Roofing Nails

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>⅛</td>
<td>0.106</td>
<td>0.625</td>
<td>130</td>
</tr>
<tr>
<td>02</td>
<td>3/₄</td>
<td>0.106</td>
<td>0.106</td>
<td>120</td>
</tr>
<tr>
<td>03</td>
<td>⅜</td>
<td>0.106</td>
<td>0.115</td>
<td>120</td>
</tr>
<tr>
<td>04</td>
<td>¾</td>
<td>0.106</td>
<td>0.110</td>
<td>120</td>
</tr>
<tr>
<td>05</td>
<td>1</td>
<td>0.106</td>
<td>0.110</td>
<td>120</td>
</tr>
<tr>
<td>06</td>
<td>1¼</td>
<td>0.106</td>
<td>0.110</td>
<td>120</td>
</tr>
</tbody>
</table>

Note—Steel wire, 1-in. flat integral steel cap, diamond point, round mechanically deformed Shank, bright finish for roofing felts. (For prepared felt roofing.)

---

All dimensions are given in inches.
### TABLE 34 Type I, Style 20—Roofing Nails

Note—Aluminum alloy wire, flat head with neoprene washer (for aluminum roofing sheet), diamond point, round, smooth, or mechanically deformed shank, as specified.

Nail = F 1667, NL, RF, N, D, -02
- Identifies an aluminum roofing nail with a neoprene washer, a length of 2, a diameter of 0.135, and a head diameter of 0.438.
  - D = deformed shank
  - S = smooth shank

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1%</td>
<td>0.135</td>
<td>0.438</td>
<td>320</td>
</tr>
<tr>
<td>02</td>
<td>2</td>
<td>0.135</td>
<td>0.438</td>
<td>280</td>
</tr>
<tr>
<td>03</td>
<td>2%</td>
<td>0.135</td>
<td>0.438</td>
<td>240</td>
</tr>
<tr>
<td>04</td>
<td>2%</td>
<td>0.135</td>
<td>0.438</td>
<td>210</td>
</tr>
</tbody>
</table>

All dimensions are given in inches.

### TABLE 35 Type I, Style 21—Shingle Nails

Note—Aluminum alloy wire, flat head, diamond point, round, smooth or mechanically deformed shank, as specified.

Nail = F 1667, NL, SH, A, S -04
- Identifies an aluminum shingle nail, smooth shank, with a length of 1\%, a diameter of 0.113, and a head diameter of 0.312.
  - D = deformed shank
  - S = smooth shank

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1%</td>
<td>0.101</td>
<td>0.191</td>
<td>1060</td>
</tr>
<tr>
<td>02</td>
<td>1%</td>
<td>0.101</td>
<td>0.191</td>
<td>860</td>
</tr>
<tr>
<td>03</td>
<td>1%</td>
<td>0.105</td>
<td>0.191</td>
<td>720</td>
</tr>
<tr>
<td>04</td>
<td>2</td>
<td>0.105</td>
<td>0.191</td>
<td>610</td>
</tr>
<tr>
<td>05</td>
<td>2%</td>
<td>0.113</td>
<td>0.200</td>
<td>180</td>
</tr>
<tr>
<td>06</td>
<td>2%</td>
<td>0.113</td>
<td>0.200</td>
<td>130</td>
</tr>
</tbody>
</table>

All dimensions are given in inches.
TABLE 36 Type I, Style 21—Shingle Nails

**Note**—Steel wire, flat head, diamond point, round, smooth (standard) or barbed (for special shingles) shank, bright or zinc coated, as specified.

- Identifies a steel shingle nail with a barbed shank, a length of 1⅛, a diameter of 0.113, a head diameter of 0.406, and bright finish.
- S = smooth shank
- Q = barbed shank
- B = bright
- Z = zinc coated

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>3d</td>
<td>1⅛</td>
<td>0.092</td>
<td>0.250</td>
<td>410</td>
</tr>
<tr>
<td>02</td>
<td>3.5d</td>
<td>1⅛</td>
<td>0.099</td>
<td>0.281</td>
<td>310</td>
</tr>
<tr>
<td>03</td>
<td>4d</td>
<td>1⅛</td>
<td>0.106</td>
<td>0.281</td>
<td>260</td>
</tr>
<tr>
<td></td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>04</td>
<td>2</td>
<td>1⅛</td>
<td>0.113</td>
<td>0.406</td>
<td>162</td>
</tr>
</tbody>
</table>

* All dimensions are given in inches.

TABLE 37 Type I, Style 22—Siding Nails

**Note**—Aluminum alloy wire, flat head (insulated), casing or countersunk head (wood), as specified, diamond point, round smooth shank or, when specified, square-barbed shank.

- Identifies an aluminum siding nail with a smooth shank, a length of 2⅛, a diameter of 0.135, a head diameter of 0.219.
- S = smooth shank
- Q = barbed shank
- F = flat head
- C = casing head
- K = countersunk head

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1⅛</td>
<td>0.113</td>
<td>0.219</td>
<td>700</td>
</tr>
<tr>
<td>02</td>
<td>1⅛</td>
<td>0.113</td>
<td>0.312</td>
<td>660</td>
</tr>
<tr>
<td>03</td>
<td>2</td>
<td>0.113</td>
<td>0.219</td>
<td>490</td>
</tr>
<tr>
<td>04</td>
<td>2⅛</td>
<td>0.135</td>
<td>0.219</td>
<td>290</td>
</tr>
</tbody>
</table>

* All dimensions are given in inches.
TABLE 38  Type I, Style 23—Slating Nails

Note—Aluminum alloy, copper or steel wire as specified. Aluminum and copper nails shall have a flat head (0.312 to 0.375-in. diameter), diamond point, and round smooth shank or, when specified, square-barbed shank. Steel nails shall have a flat, slightly countersunk head, diamond point, round smooth shank, zinc coated.

F 1667 – 03

Identifies an aluminum alloy slating nail with a length of 1½ and a diameter of 0.120 and a round smooth shank.
A = aluminum
C = copper
S = steel
R = smooth shank
B = barbed shank

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>¾</td>
<td>0.106</td>
<td>1170</td>
</tr>
<tr>
<td>02</td>
<td>1</td>
<td>0.106</td>
<td>1150</td>
</tr>
<tr>
<td>03</td>
<td>1¼</td>
<td>0.106</td>
<td>970</td>
</tr>
<tr>
<td>04</td>
<td>1½</td>
<td>0.120</td>
<td>520</td>
</tr>
<tr>
<td>05</td>
<td>1¾</td>
<td>0.135</td>
<td>520</td>
</tr>
<tr>
<td>06</td>
<td>1½</td>
<td>0.120</td>
<td>530</td>
</tr>
<tr>
<td>07</td>
<td>1⅛</td>
<td>0.135</td>
<td>430</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1</td>
<td>0.109</td>
<td>290</td>
</tr>
<tr>
<td>02</td>
<td>1¼</td>
<td>0.109</td>
<td>240</td>
</tr>
<tr>
<td>03</td>
<td>1½</td>
<td>0.120</td>
<td>210</td>
</tr>
<tr>
<td>04</td>
<td>1¾</td>
<td>0.135</td>
<td>160</td>
</tr>
<tr>
<td>05</td>
<td>1⅛</td>
<td>0.135</td>
<td>160</td>
</tr>
<tr>
<td>06</td>
<td>1⅝</td>
<td>0.120</td>
<td>160</td>
</tr>
<tr>
<td>07</td>
<td>1⅝</td>
<td>0.135</td>
<td>130</td>
</tr>
<tr>
<td>08</td>
<td>1⅞</td>
<td>0.135</td>
<td>120</td>
</tr>
<tr>
<td>09</td>
<td>2</td>
<td>0.135</td>
<td>110</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>2d</td>
<td>1</td>
<td>0.106</td>
<td>0.312</td>
<td>420</td>
</tr>
<tr>
<td>02</td>
<td>3d</td>
<td>1¼</td>
<td>0.128</td>
<td>0.375</td>
<td>220</td>
</tr>
<tr>
<td>03</td>
<td>4d</td>
<td>1⅛</td>
<td>0.128</td>
<td>0.375</td>
<td>190</td>
</tr>
<tr>
<td>04</td>
<td>5d</td>
<td>1¾</td>
<td>0.135</td>
<td>0.406</td>
<td>140</td>
</tr>
<tr>
<td>05</td>
<td>6d</td>
<td>2</td>
<td>0.148</td>
<td>0.438</td>
<td>100</td>
</tr>
</tbody>
</table>

* All dimensions are given in inches.
TABLE 39 Type I, Style 24—Rubber Heel Nails

Note—Steel wire, flat or countersunk head, as specified, needle point, round smooth shank, bright finish.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>9/16</td>
<td>0.080</td>
<td>0.154</td>
<td>04</td>
<td>1</td>
<td>0.080</td>
<td>0.154</td>
</tr>
<tr>
<td>02</td>
<td>9/32</td>
<td>0.080</td>
<td>0.154</td>
<td>05</td>
<td>11/32</td>
<td>0.080</td>
<td>0.154</td>
</tr>
<tr>
<td>03</td>
<td>3/32</td>
<td>0.080</td>
<td>0.154</td>
<td>06</td>
<td>11/32</td>
<td>0.080</td>
<td>0.154</td>
</tr>
</tbody>
</table>

^ All dimensions are given in inches.

TABLE 40 Type I, Style 25—Underlayment Nails

Note—Steel wire, flat or flat, slightly countersunk head, diamond point, round, mechanically deformed shank, bright finish.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>No./lb</th>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>S</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1</td>
<td>0.080</td>
<td>0.188</td>
<td>...</td>
<td>07</td>
<td>11/32</td>
<td>0.099</td>
<td>0.250</td>
<td>...</td>
<td>330</td>
</tr>
<tr>
<td>02</td>
<td>11/32</td>
<td>0.080</td>
<td>0.188</td>
<td>600</td>
<td>08</td>
<td>11/32</td>
<td>0.099</td>
<td>0.250</td>
<td>...</td>
<td>300</td>
</tr>
<tr>
<td>03</td>
<td>11/32</td>
<td>0.099</td>
<td>0.250</td>
<td>400</td>
<td>09</td>
<td>11/32</td>
<td>0.099</td>
<td>0.250</td>
<td>...</td>
<td>280</td>
</tr>
<tr>
<td>04</td>
<td>11/32</td>
<td>0.080</td>
<td>0.188</td>
<td>540</td>
<td>10</td>
<td>11/32</td>
<td>0.108</td>
<td>0.266</td>
<td>8d</td>
<td>170</td>
</tr>
<tr>
<td>05</td>
<td>11/32</td>
<td>0.099</td>
<td>0.250</td>
<td>360</td>
<td>11</td>
<td>11/32</td>
<td>0.109</td>
<td>0.266</td>
<td>7d</td>
<td>170</td>
</tr>
<tr>
<td>06</td>
<td>11/32</td>
<td>0.080</td>
<td>0.188</td>
<td>500</td>
<td>12</td>
<td>21/32</td>
<td>0.113</td>
<td>0.297</td>
<td>8d</td>
<td>140</td>
</tr>
</tbody>
</table>

^ All dimensions are given in inches.
TABLE 41 Type I, Style 26—Barbed Nails

Note—Steel wire, flat head, diamond point, square barbed shank, bright finish.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>Style</th>
<th>L</th>
<th>Diagonal</th>
<th>Square Dimension</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>6d</td>
<td>common</td>
<td>2</td>
<td>0.113</td>
<td>0.080 × 0.102</td>
<td>0.250</td>
<td>200</td>
</tr>
<tr>
<td>02</td>
<td>8d</td>
<td>common</td>
<td>2½</td>
<td>0.131</td>
<td>0.092 × 0.120</td>
<td>0.286</td>
<td>120</td>
</tr>
<tr>
<td>03</td>
<td>10d</td>
<td>common</td>
<td>3</td>
<td>0.148</td>
<td>0.105 × 0.135</td>
<td>0.291</td>
<td>64</td>
</tr>
<tr>
<td>04</td>
<td>20d</td>
<td>common</td>
<td>3⅛</td>
<td>0.162</td>
<td>0.113 × 0.149</td>
<td>0.312</td>
<td>59</td>
</tr>
<tr>
<td>05</td>
<td>20d</td>
<td>common</td>
<td>4</td>
<td>0.192</td>
<td>0.135 × 0.170</td>
<td>0.375</td>
<td>40</td>
</tr>
<tr>
<td>06</td>
<td>6d</td>
<td>box</td>
<td>2</td>
<td>0.099</td>
<td>0.072 × 0.089</td>
<td>0.250</td>
<td>260</td>
</tr>
<tr>
<td>07</td>
<td>6d</td>
<td>box</td>
<td>2½</td>
<td>0.113</td>
<td>0.080 × 0.102</td>
<td>0.286</td>
<td>150</td>
</tr>
<tr>
<td>08</td>
<td>6d</td>
<td>finish</td>
<td>2</td>
<td>0.092</td>
<td>0.092 × 0.083</td>
<td>0.124</td>
<td>120</td>
</tr>
<tr>
<td>09</td>
<td>6d</td>
<td>truss</td>
<td>1½</td>
<td>0.131</td>
<td>0.092 × 0.120</td>
<td>0.281</td>
<td>90</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

^ All dimensions are given in inches.

TABLE 42 Type I, Style 27—Masonry Drive Nails

Note—Hardened steel, flat head, cone pilot point, round, high pitch, multiple-start threaded shank, bright finish. When specified, masonry drive nails shall be proof lead tested.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>Thread Diameter</th>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>Thread Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>⅛</td>
<td>⅛</td>
<td>0.125</td>
<td>4</td>
<td>⅛</td>
<td>⅛</td>
<td>0.125</td>
</tr>
<tr>
<td>02</td>
<td>⅛</td>
<td>⅛</td>
<td>0.125</td>
<td>5</td>
<td>⅛</td>
<td>⅛</td>
<td>0.125</td>
</tr>
<tr>
<td>03</td>
<td>⅛</td>
<td>⅛</td>
<td>0.125</td>
<td>6</td>
<td>⅛</td>
<td>⅛</td>
<td>0.125</td>
</tr>
</tbody>
</table>

^ All dimensions are given in inches.
TABLE 43 Type I, Style 28—Escutcheon Nails

Note—Steel or brass wire, as specified, oval head, diamond point, round smooth shank.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1/4</td>
<td>0.035</td>
<td>14</td>
<td>3/4</td>
<td>0.080</td>
<td>27</td>
<td>2</td>
<td>0.080</td>
</tr>
<tr>
<td>02</td>
<td>1/4</td>
<td>0.048</td>
<td>15</td>
<td>3/4</td>
<td>0.092</td>
<td>28</td>
<td>2</td>
<td>0.092</td>
</tr>
<tr>
<td>03</td>
<td>1/4</td>
<td>0.062</td>
<td>16</td>
<td>3/4</td>
<td>0.092</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>04</td>
<td>1/4</td>
<td>0.072</td>
<td>17</td>
<td>1</td>
<td>0.048</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>05</td>
<td>1/4</td>
<td>0.080</td>
<td>18</td>
<td>1</td>
<td>0.062</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>06</td>
<td>1/4</td>
<td>0.080</td>
<td>19</td>
<td>1</td>
<td>0.072</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>07</td>
<td>1/4</td>
<td>0.080</td>
<td>20</td>
<td>1</td>
<td>0.080</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08</td>
<td>1/4</td>
<td>0.080</td>
<td>21</td>
<td>1</td>
<td>0.092</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>09</td>
<td>1/4</td>
<td>0.080</td>
<td>22</td>
<td>1 1/4</td>
<td>0.062</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1/4</td>
<td>0.092</td>
<td>23</td>
<td>1 1/4</td>
<td>0.080</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>1/4</td>
<td>0.092</td>
<td>24</td>
<td>1 1/4</td>
<td>0.092</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1/4</td>
<td>0.092</td>
<td>25</td>
<td>1 1/4</td>
<td>0.092</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>1/4</td>
<td>0.092</td>
<td>26</td>
<td>1 1/4</td>
<td>0.092</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

^ All dimensions are given in inches.

TABLE 44 Type I, Style 29—Glulam Rivet

Note—Hardened steel, flat countersunk head, diamond point, smooth shank, zinc coated, as specified.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D width</th>
<th>D thickness</th>
<th>H width</th>
<th>H thickness</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1 1/2</td>
<td>0.250</td>
<td>0.125</td>
<td>0.345</td>
<td>0.220</td>
<td>59</td>
</tr>
<tr>
<td>02</td>
<td>2 1/2</td>
<td>0.250</td>
<td>0.125</td>
<td>0.345</td>
<td>0.220</td>
<td>34</td>
</tr>
<tr>
<td>03</td>
<td>3 1/2</td>
<td>0.250</td>
<td>0.125</td>
<td>0.345</td>
<td>0.220</td>
<td>24</td>
</tr>
</tbody>
</table>

^ All dimensions are given in inches.

^ Tolerances: D width ±0.010, D thickness ±0.005, H width ±0.010, and H thickness ±0.010.
TABLE 45 Type II, Style 1—Common Cut Nails

Note—Steel or copper, flat head, bright finish.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>2d</td>
<td>1</td>
<td>07</td>
<td>7d</td>
<td>2(\frac{1}{4})</td>
<td>13</td>
<td>20d</td>
<td>4</td>
</tr>
<tr>
<td>02</td>
<td>3d</td>
<td>1(\frac{1}{4})</td>
<td>08</td>
<td>8d</td>
<td>2(\frac{1}{2})</td>
<td>14</td>
<td>30d</td>
<td>4(\frac{1}{2})</td>
</tr>
<tr>
<td>03</td>
<td>3(\frac{1}{4})d</td>
<td>1(\frac{1}{8})</td>
<td>09</td>
<td>9d</td>
<td>2(\frac{3}{4})</td>
<td>15</td>
<td>40d</td>
<td>5</td>
</tr>
<tr>
<td>04</td>
<td>4d</td>
<td>1(\frac{1}{2})</td>
<td>10</td>
<td>10d</td>
<td>3</td>
<td>16</td>
<td>50d</td>
<td>5(\frac{1}{2})</td>
</tr>
<tr>
<td>05</td>
<td>5d</td>
<td>1(\frac{3}{4})</td>
<td>11</td>
<td>12d</td>
<td>3(\frac{1}{4})</td>
<td>17</td>
<td>60d</td>
<td>6</td>
</tr>
<tr>
<td>06</td>
<td>6d</td>
<td>2</td>
<td>12</td>
<td>16d</td>
<td>3(\frac{3}{4})</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

*All dimensions are given in inches.*

TABLE 46 Type II, Style 2—Basket Cut Nails

Note—Steel, flat head, bright finish.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>T</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>3(\frac{1}{8})</td>
<td>0.049</td>
<td>0.180</td>
<td>2080</td>
</tr>
<tr>
<td>02</td>
<td>3(\frac{3}{8})</td>
<td>0.049</td>
<td>0.180</td>
<td>1500</td>
</tr>
<tr>
<td>03</td>
<td>3(\frac{1}{2})</td>
<td>0.058</td>
<td>0.203</td>
<td>1060</td>
</tr>
<tr>
<td>04</td>
<td>4</td>
<td>0.058</td>
<td>0.220</td>
<td>930</td>
</tr>
</tbody>
</table>

*All dimensions are given in inches.*
### TABLE 47  Type II, Style 3—Clout Cut Nails

Note—Steel, flat head, bright finish, blued or zinc coated, as specified (see 5).

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>T</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>¾&quot;</td>
<td>0.065</td>
<td>0.220</td>
<td>960</td>
</tr>
<tr>
<td>02</td>
<td>7/8</td>
<td>0.085</td>
<td>0.238</td>
<td>770</td>
</tr>
<tr>
<td>03</td>
<td>1</td>
<td>0.072</td>
<td>0.259</td>
<td>580</td>
</tr>
<tr>
<td>04</td>
<td>1 ⅛</td>
<td>0.0775</td>
<td>0.284</td>
<td>380</td>
</tr>
</tbody>
</table>

*All dimensions are given in inches.

### TABLE 48  Type II, Style 4—Common Cut Nails

Note—Steel, oval head, bright finish, blued, brass or copper plated, as specified.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>T</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>¾&quot;</td>
<td>0.072</td>
<td>0.2485</td>
<td>670</td>
</tr>
<tr>
<td>02</td>
<td>7/8</td>
<td>0.072</td>
<td>0.2485</td>
<td>610</td>
</tr>
<tr>
<td>03</td>
<td>1</td>
<td>0.083</td>
<td>0.2715</td>
<td>450</td>
</tr>
<tr>
<td>04</td>
<td>1 ⅛</td>
<td>0.083</td>
<td>0.2715</td>
<td>350</td>
</tr>
</tbody>
</table>

*All dimensions are given in inches.
### TABLE 49  Type II, Style 5—Cobblers Cut Nails^A

**Note**—Steel casing head, clinch point, bright finish or brass plated, as specified.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>T</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1/2</td>
<td>0.065</td>
<td>0.109</td>
<td>1950</td>
</tr>
<tr>
<td>02</td>
<td>3/8</td>
<td>0.065</td>
<td>0.109</td>
<td>1500</td>
</tr>
<tr>
<td>03</td>
<td>3/4</td>
<td>0.065</td>
<td>0.109</td>
<td>1340</td>
</tr>
</tbody>
</table>

^A All dimensions are given in inches.

### TABLE 50  Type II, Style 6—Extra-Iron Clinching Cut Nails^A

**Note**—Steel, casing head, clinch point, bright finish or blued, as specified.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>T</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1/4</td>
<td>0.049</td>
<td>0.093</td>
<td>4.130</td>
</tr>
<tr>
<td>02</td>
<td>1/8</td>
<td>0.049</td>
<td>0.093</td>
<td>3.400</td>
</tr>
<tr>
<td>03</td>
<td>1/2</td>
<td>0.049</td>
<td>0.093</td>
<td>3.040</td>
</tr>
<tr>
<td>04</td>
<td>1/48</td>
<td>0.049</td>
<td>0.093</td>
<td>2.864</td>
</tr>
<tr>
<td>05</td>
<td>1/8</td>
<td>0.049</td>
<td>0.093</td>
<td>2.260</td>
</tr>
</tbody>
</table>

^A All dimensions are given in inches.
### TABLE 51  Type II, Style 7—Hob Cut Nails

Note—Steel, square grooved head, clinch point, bright finish, or blued, as specified.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>T</th>
<th>H</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>3/4</td>
<td>0.134</td>
<td>0.360</td>
<td>270</td>
</tr>
<tr>
<td>02</td>
<td>1/2</td>
<td>0.134</td>
<td>0.360</td>
<td>260</td>
</tr>
</tbody>
</table>

* All dimensions are given in inches.

### TABLE 52  Type III, Style 1—Common Spikes

Note—These spikes shall be sheared from medium carbon sheet steel and shall have a wedged-shaped shank with a square point end narrower than the upset head end. They shall have a flat head, bright finish, or zinc coated, as specified.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>20d</td>
<td>4</td>
<td>05</td>
<td>60d</td>
<td>6</td>
</tr>
<tr>
<td>02</td>
<td>30d</td>
<td>4 1/2</td>
<td>06</td>
<td>80d</td>
<td>7</td>
</tr>
<tr>
<td>03</td>
<td>40d</td>
<td>5</td>
<td>07</td>
<td>100d</td>
<td>8</td>
</tr>
<tr>
<td>04</td>
<td>50d</td>
<td>5 1/2</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

* All dimensions are given in inches.
TABLE 53 Type III, Style 2—Gutter Spikes

Note—Steel wire, oval head, chisel point, flat head, diamond point, bright finish or zinc coated, as specified.

Identifies a gutter spike with a flat head, a length of 6, a diameter of 0.250, a head diameter of 0.562, and zinc coated; F = flat head, O = oval head, B = bright, Z = zinc.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>6½</td>
<td>0.250</td>
<td>0.562</td>
</tr>
<tr>
<td>02</td>
<td>7</td>
<td>0.250</td>
<td>0.562</td>
</tr>
<tr>
<td>03</td>
<td>8</td>
<td>0.250</td>
<td>0.562</td>
</tr>
<tr>
<td>04</td>
<td>8½</td>
<td>0.250</td>
<td>0.562</td>
</tr>
<tr>
<td>05</td>
<td>9</td>
<td>0.250</td>
<td>0.562</td>
</tr>
<tr>
<td>06</td>
<td>10</td>
<td>0.250</td>
<td>0.562</td>
</tr>
<tr>
<td>07</td>
<td>10½</td>
<td>0.250</td>
<td>0.562</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>6½</td>
<td>0.250</td>
<td>0.531</td>
</tr>
<tr>
<td>02</td>
<td>7</td>
<td>0.250</td>
<td>0.531</td>
</tr>
<tr>
<td>03</td>
<td>8</td>
<td>0.250</td>
<td>0.531</td>
</tr>
<tr>
<td>04</td>
<td>8½</td>
<td>0.250</td>
<td>0.531</td>
</tr>
<tr>
<td>05</td>
<td>9</td>
<td>0.250</td>
<td>0.531</td>
</tr>
<tr>
<td>06</td>
<td>10</td>
<td>0.250</td>
<td>0.531</td>
</tr>
<tr>
<td>07</td>
<td>10½</td>
<td>0.250</td>
<td>0.531</td>
</tr>
</tbody>
</table>

*All dimensions are given in inches.*
TABLE 54 Type III, Style 3—Round Spikes

Note—Steel wire, oval countersunk head, chisel point, flat head, diamond point, bright finish or zinc coated, as specified.

---

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>S</th>
<th>L</th>
<th>D</th>
<th>H</th>
<th>Dash No.</th>
<th>L</th>
<th>D</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>40d</td>
<td>5</td>
<td>0.2625</td>
<td>0.531</td>
<td>01</td>
<td>8</td>
<td>0.312</td>
<td>0.625</td>
</tr>
<tr>
<td>02</td>
<td>50d</td>
<td>5½</td>
<td>0.283</td>
<td>0.562</td>
<td>02</td>
<td>8</td>
<td>0.312</td>
<td>0.750</td>
</tr>
<tr>
<td>03</td>
<td>60d</td>
<td>6</td>
<td>0.283</td>
<td>0.562</td>
<td>03</td>
<td>9</td>
<td>0.312</td>
<td>0.750</td>
</tr>
<tr>
<td>04</td>
<td>⋯</td>
<td>7</td>
<td>0.312</td>
<td>0.625</td>
<td>04</td>
<td>10</td>
<td>0.312</td>
<td>0.750</td>
</tr>
<tr>
<td>⋯</td>
<td>⋯</td>
<td>⋯</td>
<td>⋯</td>
<td>⋯</td>
<td>⋯</td>
<td>8</td>
<td>0.375</td>
<td>0.750</td>
</tr>
</tbody>
</table>

---

F 1667 SPRDC

*All dimensions are given in inches.*
TABLE 55  Type III, Style 4—Barge and Boat Spikes

Note—Wrought iron, hot rolled steel rod or steel wire, square, diamond or oval head, chisel point, bright finish or zinc coated, as specified.

**Identifies a steel rod, barge and boat spike with a length of 12, oval head of 11/8, a diameter of 5/4, and zinc coated.**

- I = wrought iron
- R = steel rod
- W = steel wire
- S = square head
- D = diamond head
- O = oval head

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>D-Square</th>
<th>H</th>
<th>L</th>
<th>Dash No.</th>
<th>D-Square</th>
<th>H</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1/4</td>
<td>17/32</td>
<td>3</td>
<td>26</td>
<td>1/6</td>
<td>11/64</td>
<td>8</td>
</tr>
<tr>
<td>02</td>
<td>1/4</td>
<td>17/32</td>
<td>3 1/2</td>
<td>27</td>
<td>1/6</td>
<td>11/64</td>
<td>9</td>
</tr>
<tr>
<td>03</td>
<td>1/4</td>
<td>17/32</td>
<td>4</td>
<td>28</td>
<td>1/6</td>
<td>11/64</td>
<td>10</td>
</tr>
<tr>
<td>04</td>
<td>1/4</td>
<td>17/32</td>
<td>5</td>
<td>29</td>
<td>1/6</td>
<td>11/64</td>
<td>11</td>
</tr>
<tr>
<td>05</td>
<td>1/4</td>
<td>17/32</td>
<td>6</td>
<td>30</td>
<td>1/6</td>
<td>11/64</td>
<td>12</td>
</tr>
<tr>
<td>06</td>
<td>1/4</td>
<td>17/32</td>
<td>7</td>
<td>31</td>
<td>1/2</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>07</td>
<td>1/4</td>
<td>17/32</td>
<td>8</td>
<td>32</td>
<td>1/2</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>08</td>
<td>1/6</td>
<td>16/32</td>
<td>3 1/2</td>
<td>33</td>
<td>1/2</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>09</td>
<td>1/6</td>
<td>16/32</td>
<td>4</td>
<td>34</td>
<td>1/2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>10</td>
<td>1/6</td>
<td>16/32</td>
<td>5</td>
<td>35</td>
<td>1/2</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td>1/6</td>
<td>16/32</td>
<td>6</td>
<td>36</td>
<td>1/2</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>12</td>
<td>1/6</td>
<td>16/32</td>
<td>7</td>
<td>37</td>
<td>1/2</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>13</td>
<td>1/6</td>
<td>16/32</td>
<td>8</td>
<td>38</td>
<td>3/8</td>
<td>1 1/8</td>
<td>8</td>
</tr>
<tr>
<td>14</td>
<td>3/8</td>
<td>11/16</td>
<td>3</td>
<td>39</td>
<td>3/8</td>
<td>1 1/8</td>
<td>9</td>
</tr>
<tr>
<td>15</td>
<td>3/8</td>
<td>11/16</td>
<td>3 1/2</td>
<td>40</td>
<td>3/8</td>
<td>1 1/8</td>
<td>10</td>
</tr>
<tr>
<td>16</td>
<td>3/8</td>
<td>11/16</td>
<td>4</td>
<td>41</td>
<td>3/8</td>
<td>1 1/8</td>
<td>11</td>
</tr>
<tr>
<td>17</td>
<td>3/8</td>
<td>11/16</td>
<td>5</td>
<td>42</td>
<td>3/8</td>
<td>1 1/8</td>
<td>12</td>
</tr>
<tr>
<td>18</td>
<td>3/8</td>
<td>11/16</td>
<td>6</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>19</td>
<td>3/8</td>
<td>11/16</td>
<td>7</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>20</td>
<td>3/8</td>
<td>11/16</td>
<td>8</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>21</td>
<td>3/8</td>
<td>11/16</td>
<td>9</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>22</td>
<td>3/8</td>
<td>11/16</td>
<td>10</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>23</td>
<td>3/8</td>
<td>11/16</td>
<td>11</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>24</td>
<td>3/8</td>
<td>11/16</td>
<td>12</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>25</td>
<td>3/8</td>
<td>11/16</td>
<td>7</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

*All dimensions are given in inches.*
TABLE 56 Type IV, Style 1—Fence Staples

Note—Steel wire, bright finish or zinc coated, as specified.

- Identifies a fence staple with a length of \( \frac{3}{8} \), a diameter of 0.1483, and zinc coated.
- B = bright
- Z = zinc

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>( L )</th>
<th>( D )</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>( \frac{3}{8} )</td>
<td>0.1483</td>
<td>120</td>
</tr>
<tr>
<td>02</td>
<td>1</td>
<td>0.1483</td>
<td>110</td>
</tr>
<tr>
<td>03</td>
<td>( \frac{5}{8} )</td>
<td>0.1483</td>
<td>97</td>
</tr>
<tr>
<td>04</td>
<td>( \frac{3}{4} )</td>
<td>0.1483</td>
<td>87</td>
</tr>
<tr>
<td>05</td>
<td>( \frac{7}{8} )</td>
<td>0.1483</td>
<td>72</td>
</tr>
<tr>
<td>06</td>
<td>( \frac{1}{2} )</td>
<td>0.1483</td>
<td>61</td>
</tr>
</tbody>
</table>

^ All dimensions are given in inches.

TABLE 57 Type IV, Style 2—Poultry Netting Staples

Note—Steel wire, zinc coated.

- Identifies a poultry netting staple with a length of \( \frac{3}{4} \) and a diameter of 0.080.

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>( L )</th>
<th>( D )</th>
<th>No./lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>( \frac{3}{4} )</td>
<td>0.080</td>
<td>500</td>
</tr>
</tbody>
</table>

^ All dimensions are given in inches.
TABLE 58 Type IV, Style 3—Flat Top Crown Staples

Note—Steel wire, aluminum alloy wire, bright finish, zinc coated, cement coated or chemically etched, as specified. (For use in power tools for fastening wood and other materials to wood.)

<table>
<thead>
<tr>
<th>F 1667</th>
<th>STFC</th>
<th>S</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Identifies a steel wire, flat top crown staple with a crown width of \( \frac{3}{48} \), a wire gage of 14, a length of \( \frac{1}{16} \), and a bright finish.
  - A = aluminum wire
  - L = copper-clad wire
  - S = steel wire
  - B = bright
  - Z = zinc coated
  - C = cement coated
  - E = chemically etched

<table>
<thead>
<tr>
<th>Dash No.</th>
<th>C</th>
<th>G#</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>( \frac{3}{48} )</td>
<td>18</td>
<td>( \frac{7}{8} )</td>
</tr>
<tr>
<td>02</td>
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<tr>
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<td>08</td>
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<td>18</td>
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<td>09</td>
<td>( \frac{3}{48} )</td>
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<td>163</td>
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<td>28</td>
<td>1.00</td>
</tr>
</tbody>
</table>

^ All dimensions are given in inches.
# Dimensions and tolerances for gages of flat top crown staples:

<table>
<thead>
<tr>
<th>10 Gage</th>
<th>12 Gage</th>
<th>14 Gage</th>
<th>15 Gage</th>
<th>16 Gage</th>
<th>18 Gage</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>W</td>
<td>T</td>
<td>W</td>
<td>T</td>
<td>W</td>
</tr>
<tr>
<td>Nominal</td>
<td>0.220</td>
<td>0.140</td>
<td>0.055</td>
<td>0.112</td>
<td>0.073</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.220</td>
<td>0.140</td>
<td>0.055</td>
<td>0.112</td>
<td>0.073</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.121</td>
<td>0.156</td>
<td>0.085</td>
<td>0.108</td>
<td>0.065</td>
</tr>
<tr>
<td>Tolerance</td>
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<td>±0.0040</td>
<td>±0.0040</td>
<td>±0.0040</td>
<td>±0.0040</td>
</tr>
</tbody>
</table>
TABLE 59  Type IV, Style 3—Flat Top Crown Staples

Note—Steel wire, chisel point, tin plated, zinc coated or lacquer finish, as specified, cohered together in strips. (For use in staple tackers or machines.) The number per strip shall be as specified and shall be suitable for use in the make and model of tool specified.

<table>
<thead>
<tr>
<th>F 1667 STFC</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td></td>
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<tr>
<td>02</td>
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<tr>
<td>03</td>
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<tr>
<td>08</td>
<td></td>
</tr>
<tr>
<td>09</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 60  Type IV, Style 4—Round or “V” Crown Staple

Note—Steel wire or copper-clad wire, bright finish, zinc coated, cement coated or chemically etched, as specified. (For use in power tools for fastening wood and other materials to wood.)

<table>
<thead>
<tr>
<th>F 1667 STFC</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td></td>
</tr>
<tr>
<td>02</td>
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<tr>
<td>05</td>
<td></td>
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<tr>
<td>06</td>
<td></td>
</tr>
</tbody>
</table>

F 1667 STFC

Dash No. | L       | T x W    | C^B  |
---------|---------|----------|------|
01       | 1/16    | 0.020 x 0.030 | 0.500 |
02       | 1/4     | 0.020 x 0.030 | 0.500 |
03       | 1/16    | 0.020 x 0.030 | 0.500 |
04       | 1/4     | 0.020 x 0.050 | 0.500 |
05       | 1/16    | 0.020 x 0.050 | 0.500 |
06       | 1/2     | 0.020 x 0.050 | 0.500 |
07       | 1/2     | 0.020 x 0.050 | 0.500 |
08       | 1/2     | 0.020 x 0.050 | 0.437 |
09       | 1/4     | 0.020 x 0.050 | 0.437 |

^ For all dimensions are given in inches.

TABLE 60  Type IV, Style 4—Round or “V” Crown Staple

Note—Steel wire or copper-clad wire, bright finish, zinc coated, cement coated or chemically etched, as specified. (For use in power tools for fastening wood and other materials to wood.)

<table>
<thead>
<tr>
<th>F 1667 STFC</th>
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</thead>
<tbody>
<tr>
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<tr>
<td>02</td>
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<tr>
<td>03</td>
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<tr>
<td>05</td>
<td></td>
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<tr>
<td>06</td>
<td></td>
</tr>
</tbody>
</table>

F 1667 STFC

Dash No. | C^B  | G | L | Dash No. | C^B  | G | L |
---------|------|---|---|---------|------|---|---|
01       | 0.346 | 16 | 1/2 | 07       | 0.435 | 16 | 1/2 |
02       | 0.346 | 16 | 1/16 | 08       | 0.435 | 16 | 1/16 |
03       | 0.346 | 16 | 1/2 | 09       | 0.435 | 16 | 1/2 |
04       | 0.346 | 16 | 1/4 | 10       | 0.435 | 16 | 1/4 |
05       | 0.346 | 16 | 1/2 | 11       | 0.435 | 16 | 1/2 |
06       | 0.346 | 16 | 1   | 12       | 0.435 | 16 | 1   |

^ All dimensions are given in inches.

^ Crown width tolerances: +0.015 and -0.000.
TABLE 61 Type IV, Style 5—Preformed Staples

Note—Steel wire, chisel point, zinc or cement coated, as specified. Copper-clad wire, chisel point, tinned or other plated finish, as specified. (Hand driven.)

TABLE 62 Type IV, Style 6—Electrical Staples

Note—Insulated or uninsulated, as specified.
TABLE 63  Type IV, Style 7—Preformed Hooped Staple

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<th>Dash No.</th>
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<th>C</th>
<th>D</th>
<th>Flatten</th>
<th>No./lb</th>
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<td>01</td>
<td>⅛</td>
<td>⅛</td>
<td>0.072</td>
<td>0.057</td>
<td>720</td>
</tr>
<tr>
<td>02</td>
<td>⅛</td>
<td>⅛</td>
<td>0.083</td>
<td>0.060</td>
<td>470</td>
</tr>
<tr>
<td>03</td>
<td>¼</td>
<td>⅛</td>
<td>0.072</td>
<td>0.057</td>
<td>580</td>
</tr>
<tr>
<td>04</td>
<td>¼</td>
<td>⅛</td>
<td>0.083</td>
<td>0.060</td>
<td>430</td>
</tr>
<tr>
<td>05</td>
<td>⅛</td>
<td>⅛</td>
<td>0.072</td>
<td>0.057</td>
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</tr>
<tr>
<td>06</td>
<td>⅛</td>
<td>⅛</td>
<td>0.083</td>
<td>0.060</td>
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<td>0.057</td>
<td>670</td>
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<tr>
<td>08</td>
<td>⅛</td>
<td>⅛</td>
<td>0.083</td>
<td>0.060</td>
<td>470</td>
</tr>
<tr>
<td>09</td>
<td>⅛</td>
<td>⅛</td>
<td>0.072</td>
<td>0.057</td>
<td>530</td>
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<tr>
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<td>⅛</td>
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<td>0.083</td>
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<td>0.072</td>
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*All dimensions are given in inches.*
Standard Terminology for F16 Mechanical Fasteners

This standard is issued under the fixed designation F 1789; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This terminology standard provides a compilation of definitions for terminology used for mechanical fasteners.

1.2 Terms in this terminology are organized alphabetically. In Appendix X1 they are listed under fastener characteristic.

1.3 Additional definitions are shown in ANSI/ASME B18.12; IFI Glossary of Terms, IFI-139 and IFI-140; and SAE J412.

2. Referenced Documents

2.1 ASTM Standards:
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 563 Specification for Carbon and Alloy Steel Nuts
- E 456 Terminology for Relating to Quality and Statistics

2.2 ANSI/ASME Standard:
- B18.12 Glossary of Terms for Mechanical Fasteners

2.3 IFI Standards:
- Glossary of Terms Relating to Aerospace Fasteners
- IFI-139 Quality Assurance Requirements for Fastener Testing Laboratories
- IFI-140 Carbon and Alloy Steel Wire, Rods, and Bars for Mechanical Fasteners

2.4 SAE Standard:
- SAE J412 General Characteristics and Heat Treatments of Steels

3. Mechanical Fastener Definitions

alloy groups—an alloy group includes alloys considered to be chemically equivalent for general purpose use in specifying stainless steel bolts, hex cap screws, studs and nuts.

alloy steel—Steel is considered to be alloy when the maximum range given for manganese exceeds 1.65% or a definite minimum quantity for any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: chromium, molybdenum, nickel, or any other alloying element added to obtain a desired alloying effect.

alter—to change fastener properties such as hardness, tensile strength, surface finish, length, or other characteristics of the fastener through such processes as heat treatment, plating, and machining.

anchor bolt—a steel rod or bar, one end of which is intended to be cast in concrete while the opposite end is threaded and projects from the concrete for anchoring other material to the concrete. The end cast in concrete may be either straight or provided with an anchor, such as a bent hook, forged head, or a tapped or welded attachment to resist forces imposed on the anchor bolt as required.

annealing—a general term applied to a variety of thermal treatments applied to fasteners for the purpose of softening or homogenizing material properties. The specific types of annealing are:

full annealing—Heating steel above the upper critical transformation temperature, holding it there long enough to fully transform the steel to austenite, and then cooling it at a controlled rate, in a furnace, to below a specified temperature. A full anneal refines grain structure and provides a relatively soft, ductile material that is free of internal stresses.

intercritical annealing/isothermal annealing—Heating a steel above the lower critical transformation temperature, but below the upper-critical transformation temperature, to dissolve all the iron carbides, but not transform all the ferrite to austenite. Cooling slowly from this temperature, through the lower critical temperature, produces a structure of ferrite and pearlite that is free of internal stresses.

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the potential for bainite formation. The coarse pearlite structure greatly improves machinability of medium carbon steels.

**normalizing**—a variation of full annealing in which steel is heated above the upper critical temperature and is then air cooled in air, rather than in a furnace. Normalizing relieves the internal stresses caused by previous working, and while it produces sufficient softness and ductility for many purposes, it leaves the steel harder and with a higher tensile strength than full annealing. To remove cooling stresses, normalizing is often followed by tempering.

**process annealing**—sometimes called subcritical annealing or stress relieving, performed at temperatures just below the lower critical temperature. Process annealing neither refines grains nor redissolves cementite, but does improve the ductility and decreases residual stress in work-hardened steel.

**solution annealing**—heating an austenitic stainless steel to a temperature that puts the carbides into solution. The steel is held at this temperature long enough to achieve grain growth. It is then quenched in a medium for fast cooling, which prevents most of the carbides from reprecipitating. The process achieves optimum creep strength.

**spheroidize annealing**—a type of subcritical annealing used to soften steel and improve machinability. Heat treating fine pearlite for a long time just below the lower critical temperature of the steel, followed by a very slow cooling, produces a spheroidal or globular form of the pearlite.

**stabilization annealing**—heating an austenitic stainless steel used in severe aqueous corrosion environments by first solution annealing and then reheating to about 1600°F, and holding at that temperature. The treatment causes grain boundary precipitation of carbides, but also the hold time permits the chromium remaining in the austenite solution to redistribute within the grains, restoring corrosion resistance, even adjacent to the grain boundaries.

**applicable standards**—those having the capability of being applied in some fashion to the host standard.

**arbitration hardness location**—a prescribed location on the fastener, such as at mid-radius, using 90° intervals taken through the cross section, one diameter from the threaded end for bolts and screws.

**assembly lot**—an assembly lot may consist of a combination of different products. As long as the products that make up the assembly are in accordance with lot, the quantity of assemblies determine the sample size. Example: ten assemblies consisting of a bolt, nut, and a washer would have a lot size of ten if the bolts, nuts, and washers meet the criteria of lot. However, if any of the components in the assembly are not in accordance with lot then the ten assemblies will have to be separated into lots that meet all the requirements of lot.

**austenitic stainless alloys**—steel alloys that contain a minimum of 15% chromium and from a residual to 20% nickel. Some alloys may contain as much as 18% manganese. The metal is predominantly face centered cubic in structure and hardenable only by cold working. Essentially nonmagnetic in its wire form, it may become slightly magnetic from cold working. Austenitic stainless steels can be grouped into three categories: 300 series alloy, Cr-Ni-Mn alloys, and Cr-Ni-Mo-Ti.

**average coating thickness**—determined as either the value obtained by analytical methods or the mean value of a specified number of local thickness measurements that are evenly distributed over the significant surface.

**baking duration**—the time measured from when the plated product reaches a specified temperature in the baking furnace or oven until it is removed.

**bar**—a solid rolled or forged section that is long in relationship to its cross-sectional dimensions with a relatively constant cross-section throughout its length. Carbon and alloy steel bars are produced from hot rolled or cast billets, or from blooms rolled single strand into coils.

**barrel-plating process**—a fastener-coating process which employs a containment vessel called a barrel that is designed to move a given batch of fasteners together through each of the process steps, allowing ready ingress and egress of process solutions and rinses. As the barrel moves through the process steps, it is rotated or oscillated, causing the fasteners to cascade over one another, and in the electrocleaning and electroplating steps, and electric current is applied.

**batch average thickness**—the calculated average thickness of a coating if it were uniformly distributed on the surfaces of the items.

**bend test**—various tests in which a fastener is bent through its axis or on a round mandrel to determine the toughness and ductility of the fastener.

**bendable bolts**—bolts furnished with an altered section at some location at which the bolt will bend.

**bilateral specifications**—specifications that have both an upper and a lower value.

**bolt**—a headed and externally threaded fastener designed to be assembled with a nut.

**bolt load - elongation behavior**—when tensile loaded, a bolt will elongate elastically until stressed beyond its proportional limit where it will behave plastically.

**break loose torque**—torque applied in a removal direction necessary to start the fastener in motion from its fully preloaded installed position.

**breakaway torque**—torque necessary to start a fastener in motion after the axial load of the mating components has been reduced to zero.

**burst**—an open break in the metal during forging located on the flats or corners of bolt and screw heads, or at the periphery of a flanged or circular headed bolt or screw, or on the flats or corners of the nut.

**carbide precipitation “sensitization”**—a condition which affects some austenitic stainless steels which have been subjected to temperatures in the critical range, typically 800° to 1400°F. Complex chromium carbides precipitate and reside primarily at the grain boundaries, causing deterioration of its corrosion resistance by depleting its adjacent areas of chromium.

**carbon steel**—steel for which no minimum content is specified or required for chromium, molybdenum, nickel, or any other
element added to obtain a desired alloying effect; or steel for which maximum content specified for manganese does not exceed 1.65%. When specified, boron may be added to killed carbon steel with a maximum allowable of 0.003%.

certificate of compliance—a document or electronic record, signed by an authorized party, affirming that the supplier of the fastener or related service, or both, has met the requirements of the relevant specifications, contract, or regulation.

certificate of conformance—a document or electronic record affirming that the fastener has met the requirements of the relevant specifications, contract, or regulation.

certification—the procedure and action by a duly authorized body of determining, verifying, and attesting in writing to the qualifications of personnel, processes, procedures, or items in accordance with applicable requirements.

certified quality assurance system—a system so designated officially by a recognized accrediting body as having met all of the criteria within a national or an international third party quality system standard.

chemical anchors—chemical materials that provide anchorage between a bolt or bar and a drilled hole.

check analysis—see product analysis.

clamp load—sometimes called preload or initial load. It is a tension on a bolt or screw, which results in equal and opposite forces which exist at the interface between two members generated through the cumulative effect of tightening one or more fasteners.

cold forming—the process of forming material below the recrystallization temperature by forcing or pressing metal into various dies.

cold heading quality material—a material that has dimensional, chemical, and residual limits such that it will successfully form a given fastener geometry when machine-applied pressure produces a metal flow that results in the desired geometry. Additionally, subsequent treatment as necessary to achieve given mechanical properties results in a fastener with freedom from internal or external imperfections that would impair its intended use.

commingling—mixing of fasteners from different lots that are of the same grade and size in the same container.

common cause—common cause variation affects all the individual values of the process output being studied. In control chart analysis, it appears as part of the random process variation.

compressible-washer-type direct tension indicator—a direct tension indicator having the capability of indicating the achievement of a required minimum bolt tension by the degree of its plastic deformation.

compression load—a load which tends to compress or shorten the member. The value for compressive strength may depend upon the degree of distortion.

cone proof load—inch series—a calculated value derived from the formula

\[ CPL = (1 - 0.30D) \times f \times A_s \]  

where:
- \( D \) = nominal diameter of nut (in.),
- \( f \) = specified proof stress of nut (psi), and
- \( A_s \) = tensile stress area of nut (in.$^2$).

To meet the requirements of the cone proof load test, the nut shall support its specified cone proof load without stripping or rupture.

cone proof load—metric series—a calculated value derived from the formula

\[ CPL = (1 - 0.012D)f \times A_s \times 0.001 \]  

where:
- \( CPL \) = cone proof load (kN),
- \( D \) = nominal diameter of nut (mm),
- \( f \) = specified proof stress of nut (MPa), and
- \( A_s \) = tensile stress area of nut (mm$^2$).

To meet the requirements of the cone proof load test, the nut shall support its specified cone proof load without stripping or rupture.

cone proof load test—a test performed using a conical washer and threaded mandrel to determine the influence of surface discontinuities (that is, forging cracks or seams) on the load-carrying capability of hardened steel nuts. The test includes a simultaneous dilation and stripping action of the nut.

conical washer—a washer that has a crown height that flattens under load and is partially recovered following load removal.

consensus standard—a widely available standard developed by ASTM, ASME, SAE, ISO, or any other standards-setting organization which has under its structure those parties which include users, producers, and other interested persons.

control limit—limits on a control chart which are used as criteria for signaling the need for action, or for judging whether a set of data does or does not indicate a state of statistical control.

control plan—a written description of a system for controlling fasteners and the processes used in their manufacture. Three distinct phases are used in a control plan, including prototype, pre-launch, and production.

corrosion resistance—the ability of a fastener to resist corrosion under specified conditions.

crack—a crystalline fracture passing through or along the grain boundaries which is normally caused by overstressing the metal during manufacturing, such as forging, forming, or heat treating.

cut thread—produced by removing material from the surface with a form cutting tool.

decarburization—a loss of carbon from the surface layer of the fastener, normally associated with heat treatment.

defect—a departure of a quality characteristic from its intended level or state (or the sum of departures of different quality characteristics) that occurs with a severity sufficient to cause a fastener not to satisfy intended normal, or reasonably foreseeable, usage requirements. The term defect...
is appropriate for use when a quality characteristic is evaluated in terms of its usage.

deoxygenation—a process of reducing the oxygen content from steel during the process of steel making, either by adding strong oxide forming elements, such as silicon or aluminum, or by the process of vacuum degassing to such a level that no oxidation of carbon or other elements takes place during solidification of steel.

destructive test—a test to determine the properties of a material or the behavior of an item which results in the destruction of the sample or item.

detection process—a past-oriented strategy of quality control that attempts to identify the nonconforming product after it has been produced, and then to separate it from the conforming product.

detection system—a system which relies on final inspection as the primary means of controlling the quality of finished fasteners.

distributor—a person or organization who purchases fasteners for the purpose of reselling them. A distributor may or may not alter the fasteners prior to resale. (Significant alterations and insignificant alterations are defined separately.)

ductility of externally threaded fasteners—the ability of a fastener to deform before it fractures. Machined test specimens made from a fastener allow the measurement of elongation and reduction of area which are criteria used to evaluate the specimen. However, since yielding and fracture normally occur in the screw threads, these are impractical for the actual fastener. Hardness and the wedge tensile test are ductility indicators for the actual fastener. The lower the ratio of its specified minimum yield strength to its specified minimum tensile strength, the greater the fastener ductility.

effective case depth—the perpendicular distance from the surface of a hardened case to the furthest point where a specified level of hardness is maintained.

elongation—the increase in length of the gage length expressed as a percentage of the original gage length.

endurance limit—the maximum stress below which a bolt or screw can presumably endure an infinite number of stress cycles.

end user—the party that installs the mechanical fastener during assembly of a component or product.

environmental hydrogen embrittlement—can be “corrosion-assisted hydrogen embrittlement” caused by the liberation of hydrogen during the corrosion process, which is absorbed as atomic hydrogen, resulting in embrittlement under certain conditions of material strength and applied external stress. The end result is brittle failure. The hydrogen may also be absorbed from other external chemical sources.

extensometer—a device for sensing the elongation of fastener material while it is subjected to tensile stress, for the purpose of measuring linear deformation under controlled test conditions.

eye bolt—a bolt having a head which is a closed or open ring which as a threaded shank and has a defined breaking strength, proof load, and tensile strength.

fastener—see mechanical fastener.

fastener electroplating—the electro-deposition by electrolysis of an adherent metallic coating upon a fastener serving as an electrode. This coating may function as protective, decorative, or in a defined engineering function such as wearability or abrasive resistance.

fastener manufacturer—the organization or firm that procures a raw material, fabricates it into a mechanical fastener, and processes it to have certain mechanical properties.

fastener quality—the conformance of a fastener to its specification for dimensions, mechanical properties, performance requirements, and other requirements of a specification.

fastener specification—a precise statement of a set of requirements to be satisfied by a fastener, its material, or its processing. It also indicates the procedure used to determine whether the requirements given are satisfied.

fastener standard—a document which details the attributes of a finished fastener and includes such characteristics as geometry, material or chemistry, heat treatment, finish, lot size, and packaging.

fastener tensile stress area—an assumed cross sectional area of a threaded fastener through the thread, which is used when computing the load a fastener can support in tension.

fastener testing—the determination or verification that the fastener meets its specification requirements.

fatigue limit—see endurance limit.

fatigue strength—the maximum stress on an externally threaded fastener which can be tolerated for a specified number of repeated cycles prior to failure.

fold—a doubling over of metal which occurs during forging at or near the intersection of diameter changes which are found on the shoulders, heads, or shanks of bolts and screws, or on nuts at the intersection of diameter changes on the top face or on the bottom face.

forging cracks—occur during fastener manufacturing at the cutoff or forging operations and are located on the top of the head or on the raised periphery of indented head bolts and screws.

full size specimen—tension test specimen consisting of a completed fastener for testing in the ready to use condition without altering the configuration.

grade identification symbols—inch series standardized symbols denoting the combination of the fastener’s base material, its strength properties, its performance capabilities, and the engineering standard against which it was produced.

hardness—a measure of a material’s ability to resist abrasion or indentation, or both.

head-to-shank integrity—the assurance that a headed fastener under load is able to meet its mechanical and performance requirements without failure at the junction of the head to shank.

heat analysis—a chemical analysis of a given heat by the producer which determines the percentages of its elements.

heat resistance—the extent to which a material retains useful properties as measured during exposure of the material to a specified temperature and environment for a specified time.

high strength bolts—a term which is used commercially to denote ASTM A 325 or A 490 bolts which are primarily used in construction applications.
high temperature fastener alloys—those alloys that will
maintain their anticipated strength and characteristics within
the high temperature range.
high temperature for mechanical fasteners —this term is
generally understood to refer to a temperature range of
approximately 500°F (260°C) to 1800°F (982°C).
hot dip galvanizing—immersion of fasteners in a bath of
molten zinc for a controlled time period to obtain specified
coating weight or thickness.
hot forming—heat is applied to wire or rod to enhance metal
flow into dies using machine applied pressures as opposed to
metal removal by cutting for forming purposes.
hydrogen embrittlement, internal—see internal hydrogen
embrittlement.
impact strength—often referred to as impact energy; it is the
amount of energy required to fracture a fastener, usually
measured by either an Izod or Charpy test.
inch threaded Class 2A coating thickness—a coating thick-
ess which does not exceed ¼ of the allowance for Class 2A
threads to avoid interference.
indentation hardness—the resistance of a material to inden-
tation. This is the usual type of hardness test in which a
pointed or rounded indenter is pressed into a surface under a
substantially static load.
in-process control—a system that provides a method to detect
the variation of product characteristic(s) during manufactur-
and processing and initiates corrective action to maintain
the product characteristic(s) within its specified limits.
in-process sampling inspection—a random sample of product
drawn from prescribed points of the processing stream
(usually characteristic sensitive) and performing specific
inspections and tests to determine conformance of the
product at that point of the processing stream.
inspection—process of measuring, examining, testing, gaging,
or using other procedures to ascertain the quality or state of,
detect errors or defects in, or otherwise appraise materials,
products, services, systems, or environments to a preestab-
lished standard.
inspection test—a fastener or its selected characteristics tested
in process or after manufacture to determine conformance of
the fastener or its selected characteristics to the manufactur-
ing specifications.
inspection torque—the torque necessary to maintain tighten-
ing motion in a fastener at its fully preloaded installed
tension.
internal hydrogen embrittlement—embrittlement caused by
residual hydrogen from fastener processing, such as cleaning,
pickling, phosphating, or electroplating.
ladle analysis—see heat analysis.
liquid medium—a liquid used to quench a steel fastener to
achieve desired mechanical properties. The selection of the
medium must be compatible with the basic material and
geometry to avoid quench cracks.
local thickness—mean of the thickness measurements of
which a specified number is made within a reference area.
locking ability—a characteristic intentionally manufactured or
added to a fastener to resist loosening.
lot—a quantity of product of one part number that has been
processed essentially under the same conditions from the
same heat treatment lot and produced from one mill heat of
material and submitted for inspection at one time.
lot sampling inspection—a random sample drawn from a lot
and performing specified inspections and tests to determine
the acceptability of the lot.
low carbon martensite—the as-quenched phase of low carbon
steels, particularly to which Boron has been intentionally
added to increase the hardenability of the material, and some
stainless steels.
machined specimen—a test specimen machined from a full-
size fastener to specific dimensions to standardize test
results; often specified when a full-size fastener cannot be
reasonably or practically tested.
macro-etch test—immersion of a prepared fastener specimen
into a hot acid or aggressive media followed by examination
of the etched surface. The examination is done with the
unaided eye or at magnification not exceeding 10×.
macrograph—a photographic reproduction of any object that
has not been magnified more than ten times.
macroscopic—visible either with the naked eye or under low
magnification (as great as about ten diameters).
microstructure—the structure of metal as revealed by mac-
roscope examination.
magnetic permeability—the degree which a material becomes
magnetically attractive.
machter manufacturer—see fastener manufacturer.
martensitic alloys—iron-chromium alloys with 12% to 17%
chromium and sufficient carbon to permit strengthening by
conventional heat treatment.
material lap—a longitudinal surface discontinuity extending
into rod, bar, or wire, caused by doubling over of metal
during hot rolling.
material review—an evaluation by a team of fastener experts
to determine the fasteners’s fitness for general use, fitness for
intended use, or fitness for specified use.
material specification—a proprietary or consensus standards
document which defines the material, acceptable chemical
limits, and other requirements used in fastener manufactur-
ing.
material test report—a written document or electronic record,
signed by an authorized party, attesting that the raw material
is in accordance with specified requirements, including the
actual results of all required chemical analyses, tests, and
examinations.
maximum hardness—a hardness specified in fastener stan-
dards above which the fastener is considered nonconforming
to the standard.
mechanical deposition—a coating process in which particles
of the plating metal are impacted against the fastener surface
such that cold welding of the plating metal to the fastener
surface is accomplished.
mechanical fastener—a mechanical device that holds or joins
two or more components in definite positions with respect to
each other and is often described as a bolt, nut, rivet, screw,
washer, or special formed part.
mechanical properties—fastener characteristics which relate to its reaction to applied loads; these properties may be those of the basic raw material or result from the manufacturing process.

metallography—the study of the structure of fastener metals using optical or electronic microscopes that produce a magnified image of the material structure of the fastener.

microstructure—the structure of a given metal revealed by microscopic observation of an etched surface.

minimum hardness—the hardness value of a fastener below which it is not in conformance with the specification.

minimum local thickness—the lowest local thickness value on the significant surface of a single article.

modulus of elasticity—for a given material, the ratio of unit stress to unit strain within its elastic range which may be used as a measure of stiffness. Sometimes called Young’s Modulus.

nick—an indentation on the surface of a bolt, nut, screw, or stud. Also referred to as a gouge.

nonconformance—a fastener or fastener component which does not conform to a specification or other inspection standard.

nonferrous alloys—alloys that do not contain iron as their main constituent although iron may be present as an impurity. The most common nonferrous groups are copper, nickel, aluminum, and titanium alloys.

nut—an internally threaded product intended for use on external or male screw threads such as a bolt or a stud for the purpose of tightening or assembling two or more components.

part identifying number (PIN)—an alphanumeric sequence used to code B18 fasteners. The system was developed by ASME Standards Committee B18.

passivation—the process of forming an oxide film on the surface of stainless steel fasteners by chemical treatment, usually nitric acid solution, to improve corrosion resistance of stainless steel fasteners.

performance properties—design feature(s) manufactured into the fastener to achieve a specific characteristic relative to the fastener application, such as torque-tension.

physical properties—those properties inherent in the raw material which remain unchanged or exhibit only slight alteration in the fastener following manufacture.

plain washer—a fastener accessory that accepts a bolt or screw through its center hole and provides a surface to distribute bearing stress. It also serves to provide a surface for head or nut rotation during tightening.

plastic deformation—permanent distortion of a material under the action of applied stresses.

plasticity—the ability of the metal to undergo permanent deformation without rupture.

plating—deposition of an adherent metal onto the surface of the base metal of the fastener. A specific process should be specified; that is, electroplating, hot dip galvanizing, mechanical deposition, etc.

precipitation hardening alloys—a group of alloys that can be hardened by participation of second phases or intermetallic compounds by cooling during a thermal or thermal-mechanical aging treatment.

pre-launch production plan—a written description of the dimensional, mechanical, chemical, and performance testing that will be carried out during initial production, prior to full production.

prevailing torque—torque necessary to rotate a fastener relative to its mating component with the torque being measured with the fastener in motion and zero axial load in the assembly.

prevention process—a future-oriented strategy that, through analysis and action toward correcting the process itself, enriches quality through continuous improvement activities.

prevention system—a system which outlines advance quality planning, in–process inspection, process controls, and statistical methods to control the processes and seek continuous improvement.

private label distributor—a distributor who, by prearrangement with a manufacturer, markets fasteners identified with the distributor’s unique identification marking and who assumes responsibility for the fasteners.

process flow—the current or anticipated sequential process steps required to produce a fastener.

process parameters—combination of conditions originating from people, measurement, materials, method, and environment that contribute to a given output.

product analysis—a chemical analysis performed on the finished fastener to verify that the chemical composition is within specified limits.

production plan—a complete written plan of fastener and process characteristics, process controls, tests, and acceptance procedures that will occur during full production.

proof load—a tension-applied load that the fastener must support without evidence of permanent deformation. (For most carbon or alloy steel fastener strength grades or property classes, proof loads are established at approximately 90% to 93% of the expected minimum yield strength.)

property class—a system of strength classifications used for bolts, nuts, and screws manufactured to metric standards.

property class symbols—metric series standardized symbols denoting the combination of the fastener’s base material, its strength properties, its performance capabilities, and the engineering standard against which it was produced.

proportional limit—the greatest stress that the material is capable of sustaining without a deviation from the law of proportionality of stress to strain (Hooke’s Law). In many cases, the elastic limit is so close to the proportional limit that no distinction is made.

prototype plan—a written description of the dimensional, mechanical, chemical, and performance tests that will be used to facilitate the building of a prototype.

qualification (personal)—the characteristics or abilities gained through training or experience, or both, that enable an individual to perform a required function.

quality assurance—all of the planned and systematic activities carried out for the purpose of establishing that a fastener
lot is within specified tolerances, limits, and other requirements.

**quality assurance program**—the specific requirements within a quality system which serves to focus the activities of a fastener organization in pursuit of stated requirements of the quality plan.

**quality assurance system**—a manufacturing system for assuring quality that incorporates either a written control plan or employs other acceptable methods for controlling quality. This may include provisions for prototype development, initial production, and full production including advanced quality planning, continuous improvement, defect prevention, and in-process controls of dimensional, mechanical, and performance characteristics of the fastener.

**quench cracks**—surface discontinuities which usually transverse an irregular or erratic course on the surface of the fastener which may occur because of excessive high thermal or transformation stresses, or both, during fastener heat treatment.

**rack-plating process**—a fastener coating process in which individual fasteners are placed on a support called a rack which moves the fasteners together through the process steps while providing ready ingress and egress of processing solutions and rinses. In process steps which utilize an electric current, the rack serves to maintain electrical continuity.

**random sampling**—a method of sample selection for fasteners in a lot where each fastener has an equal and independent chance of being selected for the sample.

**raw material manufacturer**—an organization which manufactures rod, wire, or bar, used to produce mechanical fasteners, from raw material it manufactures and controls in terms of chemistry and mechanical properties.

**reduced diameter body**—a fastener having a body diameter not less than the minimum pitch diameter of its thread nor more than its minimum full body diameter.

**reduction of area**—the difference, expressed as a percentage, of the original cross sectional area of a tensile test specimen at its minimum cross section after fracture.

**referenced standards**—those which contain guidelines or nondated requirements germane to one or more elements of the host standard.

**registered quality assurance system**—a system that a registration body has found to be in compliance with a designated quality system standard.

**registration**—an evaluation of a fastener manufacturing facility’s quality assurance system by an accredited registration body resulting in a certification of full compliance with a designated quality system standard; the registration body shall be accredited by a third party registration accreditation body, for example, ANSI/RAB.

**related standards**—those standards which possess certain relevance to the host standard in terms of understanding its concepts, but do not of necessity specify any mandated requirements.

**repeatability**—the variation in the values of measurement obtained when one operator uses the same gage for measuring identical characteristics of the same parts.

**reprocess**—the repeating of a process that has already been conducted on a fastener as part of the standard requirement.

**residuals**—measurable elements present in a metal or alloy which were not intentionally added to meet a specification requirement.

**resilience**—the tendency of a material to return to its original shape after the removal of a stress.

**responsibility for the fastener**—the party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested, and inspected in accordance with the specification and meets all of its requirements. A 563

**responsible party**—the responsible party for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fasteners were manufactured, sampled, tested, and inspected in accordance with applicable specifications and meets all of the requirements.

**review**—a deliberately critical examination, including observation of plant operation, evaluation of audit results, procedures, certain contemplated actions, and after-the-fact investigations of abnormal conditions.

**rod**—produced from hot rolled or cast billets, usually rolled in a multiple strand mill to a round cross section then coiled into one continuous length.

**roll thread**—a thread produced by action of a form tool which, when pressed into the surface of a blank, displaces material radially.

**roof and rock bolts**—headed hot-rolled bars with cold-rolled or machine-cut threads at the end to be used with anchorage devices to hold up mine roofs, hold back walls, or hold down equipment or foundations.

**rotational capacity test**—a test in which a zinc-coated bolt is inserted in a steel joint or tension measuring device, assembled with a lubricated zinc coated nut, and initially tightened to not less than 10% of the bolt proof load. After initial tightening, the nut is rotated through specified degrees of rotation.

**routine hardness locations**—hardness readings made on prescribed fastener surfaces, such as wrench flats, unthreaded shank, bearing face, etc., after removal of oxide, platings, or other coating materials. Used for testing the hardness of a finished fastener.

**salt spray test**—a corrosion test in which the metallic fastener specimens are exposed to a fine mist of salt water solution, either continuously or intermittently.

**screw**—a mechanical fastener having basic design characteristics which facilitate its assembly into a tapped hole or to form its own threads during installation.

**screw thread**—a helical ridge generally of uniform cross section formed on a cylindrical surface used to facilitate assembly of mechanical components.

**seam**—a straight or smooth curved line surface discontinuity running longitudinally on the fastener thread, shank, and head.

**secondary manufacturer**—any entity, including the original manufacturer, that alters the fastener.

**secondary processing**—a process that is performed to a fastener in order to add further value, such as drilling,
assembly with other fastener components, lubricating, coating, and machining. This product may already be tested (or certified when applicable, or both) in compliance with a given standard.

shall—used to denote a mandatory requirement.

shear burst—an open break in the fastener metal at approximately 45° to the product axis, usually at the periphery of fasteners having flanged or circular heads or on the side of hex heads.

shear strength—the maximum load applied normally to a fastener’s axis that can be supported prior to fracture. Single shear is load occurring in one transverse plane, thus cutting the fastener into two pieces; double shear is load applied in two planes so that, at fracture, the fastener would be cut into three pieces.

shear stress area: bolt or screw—the area perpendicular to the fastener axis which is based on the root diameter (minor diameter) of an externally threaded bolt or screw.

should—used to denote a recommendation. Not suitable for specification use to denote mandatory requirements.

significant surface—a surface area where the minimum thickness to be met shall be designated on the applicable drawing or by the provision of a suitably marked sample. However, if not designated, significant surfaces shall be defined as those normally visible, directly or by reflection, which are essential to the appearance or serviceability of the fastener when assembled in normal position, or which can be the source of corrosion products that deface visible surfaces on the assembled fastener.

significantly alter—any action which would change the mechanical or performance capabilities of the fastener following its original manufacture.

solution treat—see annealing, solution annealing.

special cause variation—special cause variation is intermittent, unpredictable and unstable. In control chart analysis, it is signaled by a point beyond the control limits, a run, or some other nonrandom pattern of points within the control limits.

spherical washers or seats—washers comprised of two mating washer components: one component is a washer having one flat side and a convex spherical surface on the other side. The other component is a washer having one flat side and a concave spherical depression machined into the other side. The two convex and concave spherical portions are mated and fit together to make up one spherical washer unit.

spheroidize—see annealing, spheroidize annealing.

stainless steel—steel which has been alloyed with chromium ranging from 10% to less than 30%. Other alloying elements may also be added.

statistical control—exists when all special causes of variation have been eliminated from a process and only common causes remain.

statistical process control—the use of statistical techniques, such as control charts, to analyze a process or its outputs so as to take appropriate actions to achieve and maintain a state of statistical control and to improve the process capability.

strain—deformation produced on a fastener by an outside force.

strain hardening—an increase in hardness and strength resulting from plastic deformation by cold working.

strength grade—a system of strength classifications used for bolts, nuts, and screws made to inch standards.

stress—force expressed in units per unit of area, which represents resistance that a fastener offers to deformation.

stress corrosion cracking—a cracking phenomena that occurs when an installed fastener under stress is exposed to a corrosive service environment.

structural bolt—a heavy hex head bolt having a controlled thread length intended for use in structural connections and assembly of such structures as buildings and bridges.

subgroup—one or more events or measurements used to analyze the performance of a process.

surface discontinuities—irregularities that occur prior to or during the manufacturing or processing of the fastener. These may include cracks, head bursts, shear bursts, seams, folds, thread laps, voids, tool marks, and nicks or gouges.

systematically selected samples—a commonly used technique whereby specimens are chosen for inspection or testing based on stated criteria of a sampling plan, such as occurs during process-control charting, during tooling changes, or at specific timed intervals.

tensile strength, fastener—see ultimate strength.

test report—a written document or electronic record, signed by an authorized party, which contains sufficient data and information to verify that the tested fastener properties conform to the particular specification requirements.

thread lap—a doubling over of metal on the thread which is created during roll threading operations.

threaded deformed bar—a steel bar that has a continuous hot-rolled pattern of thread-like deformations along its entire length that allows a nut and coupler to thread onto the bar.

tool marks—longitudinal or circumferential grooves of shallow depth produced by the movement of manufacturing tools over the bolt, nut, or screw surface.

torsional strength—a load, usually expressed in terms of applied torque, at which the fastener fails by being twisted off about its axis.

total case depth—the distance measured perpendicularly from the surface of a hardened case to a point where differences in chemical or physical properties of the case and core no longer can be distinguished.

toughness—the ability of a fastener to absorb energy and to deform plastically before fracture.

traceability—the ability to verify the manufacturing history, raw material, heat number, location, or application of an item by means of recorded identification.

ultimate tensile load—the maximum tensile-applied load or force a fastener can support prior to or coincidental with its fracture, and normally expressed in terms of pounds or Newtons.

user—see end user.

verification—an act of confirming, substantiating, and assuring that an activity or condition has been implemented in conformance with the specified requirements.

Vickers hardness test—standard method for measuring the hardness of metals, particularly those with extremely hard
surfaces; the surface is subjected to a standard pressure for a standard length of time by means of a pyramid-shaped diamond. The diagonal of the resulting indentation is measured under a microscope and the Vickers hardness value is then read from a conversion table.

**void**—a shallow pocket or hollow on the surface of a fastener because of nonfilling of metal during forging.

**warm heading or working**—a forming method in which material is heated to a given temperature to improve formability before heading. The temperature used is below the recrystallization point or transformation temperature of the metal being formed.

**washer-retainer crack**—opening in the lip or hub of metal used to retain a washer on a nut.

**weathering steels**—steels having added alloying elements to enhance the resistance to atmospheric corrosion.

**wedge tensile strength**—the ultimate strength determined by testing with the use of a wedge with a prescribed angle.

**wedge tensile test**—a tensile test performed on various headed fasteners and studs using a wedge of prescribed dimensions and hardness, and in a prescribed manner for the purpose of verifying good head quality or ductility, or both.

**wire**—used extensively in fastener manufacturing. It is produced from hot rolled or annealed rods or bars by cold drawing. Steel sizes range from 0.062 to 1.375 in.

**workmanship**—the expected absence of imperfections affecting serviceability of a fastener. Often used to describe a finish free from injurious burrs, seams, laps, or irregular surfaces.

**yield strength**—the tension-applied load at which the fastener experiences a specific amount of permanent deformation, that is, the bolt has been stressed beyond its elastic limit and is in the plastic zone. It is very difficult to test full size bolts for yield strength. Because of different strain rates in the threaded section, thread runout and unthreaded shank which together comprise the stressed length, a “proof load” concept was introduced.

**Young’s modulus**—see *modulus of elasticity*.

**zero defects**—a term which indicates that no deviation from the requirements of a specification are present within a statistically valid sample drawn from a given fastener lot.
Physical Properties
Magnetic Permeability
Physical Properties
Resilience

Product Definition
Anchor Bolt
Bar
Bendable Bolts
Bolt
Chemical Anchors
Compressible-Washer-Type Direct Tension Indicator
Conical Washer
Consensus Standard
Eye Bolt
Fastener
High Strength Bolts
Mechanical Fastener
Nut
Part Identifying Number (PIN)
Plain Washer
Reduced Diameter Body
Roof and Rock Bolts
Screw
Screw Thread
Shear Stress Area: Bolt or Screw
Significant Surface
Spherical Washers or Seats
Structural Bolt
Threaded Deformed Bar
Washer-Retainer Crack

Quality Assurance
Burst
Certified Quality Assurance System
Commingling
Common Cause
Control Limit
Defect
Detection System
Fastener Quality
Fold
In-Process Sampling Inspection
Material Lap
Material Review
Nick
Nonconformance
Pre-Launch Production Plan
Prevention System
Process Parameters
Production Plan
Prototype Plan
Qualification (Personal)
Quality Assurance
Quality Assurance Program
Quality Assurance System
Random Sampling
Registered Quality Assurance System
Registration
Repeatability
Responsibility for the Fastener
Responsible Party
Review
Surface Discontinuities
Systematically Selected Samples
Thread Lap
Tool Marks
Traceability
Verification
Washer-Retainer Rack
Workmanship
Zero Defects

Supplier/User
Distributor
End User
Fastener Manufacturer
Manufacturer
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Standard Specification for
“Twist Off” Type Tension Control Structural Bolt/Nut/Washer
Assemblies, Steel, Heat Treated, 120/105 ksi Minimum
Tensile Strength1

This standard is issued under the fixed designation F 1852; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*  
1.1 This specification covers two types of heat treated, steel,
tension control bolt-nut-washer assemblies, also referred to as
“sets.” These assemblies are capable of developing a minimum
predetermined tension when installed by applying torque to the
nut, while at the same time applying a counter torque to
separate the spline end from the body of the bolt using an
appropriate spline drive installation tool.

1.2 An assembly consists of a tension control bolt with
spline end (covered by this specification) and a suitable nut and
washer covered by reference to applicable ASTM specifications.

1.3 The fasterener assemblies are intended for use in struc-
tural connections. These connections, installation procedures,
and the use of alternate design structural bolts are covered
under the requirements of the “Specification for Structural
Joints Using ASTM A 325 or A 490 Bolts,” approved by the
Research Council on Structural Connection.

1.4 The assemblies are available with either round (button
or dome) heads, heavy hex structural heads, or alternate design
heads described in Section 10 and Fig. 1, in sizes ½ to 1 ½ in.
inclusive, in two types specified in Section 4.

1.5 Terms used in this specification are defined in Termi-
nology F 1789 unless otherwise defined herein.

1.6 The following precautionary statement pertains only to
the test method portions, Sections 13 and 14, of this Specifi-
cation: This standard does not purport to address all of the
safety concerns, if any, associated with its use. It is the
responsibility of the user of this standard to establish appro-
priate safety and health practices and determine the applica-
tility of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards: 2

A 29/A 29M Specification for Steel Bars, Carbon and Alloy,
Hot-Wrought and Cold-Finished, General Requirements

A 194/A 194M Specification for Carbon and Alloy Steel
Nuts for Bolts for High Pressure or High Temperature
Service, or Both

A 242/A 242M Specification for High-Strength Low-Alloy
Structural Steel

A 325 Specification for Structural Bolts, Steel, Heat
Treated, 120/105 ksi Minimum Tensile Strength

A 563 Specification for Carbon and Alloy Steel Nuts

A 588/A 588M Specification for High-Strength Low-Alloy
Structural Steel with 50 ksi [345 MPa] Minimum Yield
Point to 4-in. [100-mm] Thick

A 709/A 709M Specification for Carbon and High-Strength
Low-Alloy Structural Steel Shapes, Plates, and Bars and
Quenched-and-Tempered Alloy Structural Steel Plates for
Bridges

A 751 Test Methods, Practices, and Terminology for
Chemical Analysis of Steel Products

A 871/A 871M Specification for High-Strength Low-Alloy
Structural Steel Plate With Atmospheric Corrosion Resis-
tance

B 695 Specification for Coatings of Zinc Mechanically
Deposited on Iron and Steel

D 3951 Practice for Commercial Packaging

F 436 Specification for Hardened Steel Washers

F 606 Test Methods for Determining the Mechanical Prop-
erties of Externally and Internally Threaded Fasteners,
Washers, and Rivets

F 788/F 788M Specification for Surface Discontinuities of
Bolts, Screws, and Studs, Inch and Metric Series

F 1470 Guide for Fastener Sampling for Specified Mechani-
cal Properties and Performance Inspection

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1 This specification is under the jurisdiction of ASTM Committee F16 on
Fasteners and is the direct responsibility of Subcommittee F16.02 on Steel Bolts,
Nuts, Rivets and Washers.


2 For referenced ASTM standards, visit the ASTM website, www.astm.org, or
contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM
Standards volume information, refer to the standard’s Document Summary page on
the ASTM website.

*A Summary of Changes section appears at the end of this standard.

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3. Terminology

3.1 Definitions of Terms Specific to This Standard:

A These values are the same as the dimensions for Heavy Hex Structural Bolts specified in ANSI B18.2.1.

B The spline length (LS) and across the flat (S) dimensions are used for reference only. The grooved spline design may vary in size and shape.

**FIG. 1 Head and Spline Dimensions Inches**

3.1.1 *assembly lot*—an assembly lot for purposes of assigning identification numbers and from which test samples shall be selected, shall consist of one combination of component lots. That is, one tension control bolt component lot, one nut component lot, and one washer component lot which are shipped as an assembly.

3.1.2 *component lot*—A component lot, for the purpose of assigning an identification number and from which test samples shall be selected, shall consist of all tension control bolts, all nuts or all washers processed essentially together through all operations to the shipping container, of which each component has the following common characteristics: heat number (mill heat); ASTM designation and grade or type, as applicable; nominal dimensions (size) and head style; heat treatment lot; and coating lot, if applicable.

3.1.3 *secondary processing*—any processing performed by any entity on the assemblies or individual components after initial testing.

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1 Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036
2 Available from American Institute of Steel Construction (AISC), One E. Wacker Dr., Suite 3100, Chicago, IL 60601-2001.
3.1.4 **tension control bolt**—a bolt that includes an integral spline end which extends beyond the threaded portion of the bolt. The fastener is to be tightened using a special electric wrench and socket system which has an inner socket that engages the spline end and with an outer socket that engages and turns the nut.

3.1.5 **tension control bolt assembly**—a tension control bolt, nut and washer combination.

4. **Classification**

4.1 The tension control bolts are designed by type denoting chemical composition as follows:

4.1.1 Type 1—Plain carbon, carbon boron, or alloy steel.

4.1.2 Type 3—Weathering steel. Atmospheric corrosion resistance and weathering characteristics are comparable to that of steels in Specifications A 242/A 242M, A 588/A 588M, A 709/A 709M, A 871/A 871M, (see 7.1.2).

5. **Ordering Information**

5.1 Orders for assemblies shall include the items of information below. Optional items not on the purchase order shall be considered as not being required, (see Note 1):

5.1.1 Quantity of assemblies

5.1.2 Size, include nominal tension control bolt diameter and length (without the spline end)

5.1.3 Name of product, that is, twist off type tension control bolt/nut/washer assemblies,

5.1.4 Head Style (see 10.1.1),

5.1.5 Type of Assembly, that is; Type 1 or Type 3

5.1.6 ASTM designation and year of publication,

5.1.7 Mechanically zinc coated, if required, and

5.1.8 Special requirements, if required

**Note 1**—A typical order description follows: 2520 assemblies, ¾ in. diameter by 2 in. long Tension Control Bolt/Nut/Washer Assemblies, Round Heads, Type 1 ASTM F 1852.

6. **Materials and Manufacture**

6.1 **Heat Treatment:**

6.1.1 Tension control bolts made from carbon or carbon boron steel shall be heat treated by quenching in a liquid medium from above the austenitizing temperature and then tempering by reheating to a temperature of at least 800°F (425°C).

6.1.2 Tension control bolts made from alloy steel shall be heat treated by quenching in oil from above the austenitizing temperature and then tempering by reheating to a temperature of at least 800°F (425°C).

6.2 **Thread**—The threads of tension control bolts shall be rolled.

6.3 **Mechanical Zinc Coating:**

6.3.1 When zinc coating is specified, each component of the assembly shall be mechanically zinc coated. The coating shall conform to Specification B 695, Class 50 Type 1 as a minimum thickness.

6.3.2 Hot dip zinc coating shall not be permitted.

6.4 **Lubrication**—All nuts, plain and zinc coated, shall be lubricated. The lubricant shall be clean and dry to the touch.

**Note 2**—No further lubrication shall be permitted other than that applied by the manufacturer, as the type and amount of lubrication is critical to performance.

6.5 **Secondary Processing:**

6.5.1 If heat treatment, zinc coating, lubrication or other processing affecting properties are performed by any source on any unit of a component lot after the manufacturer’s test to qualify a lot has been performed, the component lot shall be treated as newly manufactured and shall be reinspected and retested in accordance with the requirements of its original manufacturing specification after such processing is completed. Retesting shall be the responsibility of the party supplying the component.

6.5.2 Secondary processing shall not be permitted to an assembly lot.

6.6 **Assembly:**

6.6.1 The assemblies shall be of the type specified by the purchaser.

6.6.2 The assemblies shall consist of one tension control bolt, with one lubricated nut and one or more washer(s).

6.6.3 Unless otherwise specified, nuts and washers used on the assemblies shall conform to the requirements of the specifications below:

<table>
<thead>
<tr>
<th>Assembly Type and Finish</th>
<th>Nut Specification, Class and Finish</th>
<th>Washer Specification, Type and Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>A 563 DH Plain</td>
<td>F 436 Type 1</td>
</tr>
<tr>
<td>Plain</td>
<td>A 194 2H Plain</td>
<td>Plain</td>
</tr>
<tr>
<td>Type 1</td>
<td>A 563 DH3 Plain</td>
<td>F 436 Type 3</td>
</tr>
<tr>
<td>Mechan. Zinc Coated</td>
<td>A 563 DH Mech. Zinc Coated</td>
<td>Mechanical Zinc Coated</td>
</tr>
<tr>
<td>Type 3</td>
<td>A 563 C Plain</td>
<td>F 436 Type 1</td>
</tr>
<tr>
<td>Plain</td>
<td>A 563 C3 Plain</td>
<td>F 436 Type 3</td>
</tr>
</tbody>
</table>

6.6.4 All nuts shall be Heavy Hex. All washers used in the assembly shall be circular and through hardened.

7. **Chemical Composition**

7.1 **Tension Control Bolts:**

7.1.1 Type 1 tension control bolts shall be plain carbon steel, carbon boron steel, or alloy steel, at the manufacturers option, and shall conform to one of the chemical compositions specified in Table 1.

7.1.2 Type 3 tension control bolts shall be weathering steel and shall conform to one of the chemical compositions, specified in Table 2. The selection of the chemical composition A, B, C, D, E, or F, shall be at the option of the manufacturer. See Guide G 101 for method of estimating the atmospheric corrosion resistance of low alloy steels.

7.1.3 Product analysis, when performed, shall be made from finished material representing each lot. To meet the specification, the chemical composition thus determined shall conform to the requirements specified in Table 1 or Table 2 as applicable.

7.1.4 Heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

7.1.5 For Type 1 bolts made from plain carbon steel or alloy steel, heats of steel which boron has been intentionally added shall not be permitted.
8.2.4 For bolts on which hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event of controversy over low hardness tests.

8.3 Nuts and Washers— Mechanical properties for nuts and washers shall be in accordance with the applicable specification in 6.6.3.

9. Assembly Lot Tension Test

9.1 Purpose—The assembly lot tension test shall be performed on fastener assemblies to determine the ability of the assembly to provide the required minimum tension.

9.2 Requirement—Full size completed assemblies tested in accordance with 14.4 shall develop a bolt tension when the spline end is separated from the bolt conforming to the requirements in Table 5, Column 1.

10. Dimensions

10.1 Tension Control Bolts:

10.1.1 Tension control bolts shall be furnished with either round (button or dome), heavy hex structural or alternate design heads; as specified by the purchaser.

10.1.2 The tension control bolts shall have a body conforming to the dimensions for heavy hex structural bolts specified in ANSI B18.2.1 and a spline end conforming to the dimensions in Fig. 1.

10.1.3 Head designs as specified in 10.1.1 shall have a bearing surface area and head height equal to or larger than required for heavy hex structural bolts in ANSI B18.2.1.

10.1.4 Round heads shall conform to the dimensions in Fig. 1.

10.1.5 The thread length shall be as specified in ANSI B18.2.1 for heavy hex structural bolts.

10.2 Nuts and Washers—The dimensions for nuts and washers shall be in accordance with the applicable specification specified in 6.6.3.

10.3 Threads:

10.3.1 Threads on tension control bolts shall be the Unified Coarse Thread Series as specified in ASME B1.1, and shall have Class 2A tolerances.

10.3.2 Unless otherwise specified, zinc coated tension control bolts to be used with nuts which have been tapped oversize in accordance with Specification A 563, shall have Class 2A threads before mechanically deposited zinc coating.

10.3.3 The gaging limit for bolts shall be verified during manufacture. In case of purchaser/supplier controversy over thread compliance, System 21 of ASME B18.18.3M shall be used for referee purposes.

11. Workmanship, Finish, and Appearance

11.1 Surface discontinuity limits for tension control bolts, inspection, and evaluation of the surface discontinuities, quench cracks, forging cracks, head bursts, shear bursts, seams, folds, thread laps, voids, tool marks, nicks, and gouges shall be in accordance with Specification F 788/F 788M (see Note 3).

Note 3—Specifications F 788/F 788M and F 1470 do not guarantee 100 % freedom from head bursts. Sampling is designed to provide a 95 % confidence level of freedom from head bursts in any test lot. Head bursts, within the limits in Specification F 788/F 788M, are unsightly but do not affect mechanical properties or functional requirements of the bolt.

### Table 1: Chemical Requirements for Type 1 Tension Control Bolts

<table>
<thead>
<tr>
<th>Element</th>
<th>Carbon Steel Heat Analysis</th>
<th>Product Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>0.30 to 0.52</td>
<td>0.28 to 0.55</td>
</tr>
<tr>
<td>Manganese, min</td>
<td>0.60</td>
<td>0.57</td>
</tr>
<tr>
<td>Phosphorus, max</td>
<td>0.040</td>
<td>0.048</td>
</tr>
<tr>
<td>Sulfur, max</td>
<td>0.050</td>
<td>0.058</td>
</tr>
<tr>
<td>Silicon</td>
<td>0.15 to 0.30</td>
<td>0.13 to 0.32</td>
</tr>
<tr>
<td>Boron</td>
<td></td>
<td>See 7.1.5 and 7.1.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Element</th>
<th>Carbon Boron Steel Heat Analysis</th>
<th>Product Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>0.30 to 0.52</td>
<td>0.28 to 0.55</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.60</td>
<td>0.57</td>
</tr>
<tr>
<td>Phosphorus, max</td>
<td>0.040</td>
<td>0.048</td>
</tr>
<tr>
<td>Sulfur, max</td>
<td>0.050</td>
<td>0.058</td>
</tr>
<tr>
<td>Silicon</td>
<td>0.10 to 0.30</td>
<td>0.08 to 0.32</td>
</tr>
<tr>
<td>Boron</td>
<td>0.0005 to 0.003</td>
<td>0.0005 to 0.003</td>
</tr>
</tbody>
</table>

For alloy steels, as defined by the American Iron and Steel Institute, shall be considered to be alloy when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: manganese, 1.65 %; silicon, 0.60 %; copper, 0.60 %; or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99 %; cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying elements added to obtain a desired alloying effect.

7.1.6 Compliance with 7.1.4 and 7.1.5 shall be based on certification that heats of steel having any of the listed elements intentionally added were not used to produce the bolts.

7.1.7 Chemical analysis shall be performed in accordance with Test Methods, Practices, and Definitions A 751.

7.2 Nuts and Washers—Chemical requirements for nuts and washers shall be in accordance with the applicable specification specified in 6.6.3.

8. Mechanical Property Requirements for Tension Control Bolts

8.1 Hardness: The bolts shall conform to the hardness specified in Table 3.

8.2 Tensile Properties:

8.2.1 Bolts having a length of three times the diameter or longer (see 8.2.3) shall be tested full size and shall conform to the tensile strength and proof load or alternative proof load specified in Table 4.

8.2.2 Bolts having a length less than three times the diameter are not subject to tensile tests, except as permitted in 8.2.3.

8.2.3 Bolts having a length of two times the diameter or longer shall be permitted to be tested full size for tensile properties whenever suitable test equipment is available. In such cases reference to “two times the diameter” in Table 3, 8.2.1, and 8.2.2 shall be considered to be “two times the diameter”.

A Steel, as defined by the American Iron and Steel Institute, shall be considered to be alloy when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: manganese, 1.65 %; silicon, 0.60 %; copper, 0.60 %; or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99 %; cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying elements added to obtain a desired alloying effect.

### Table 1: Chemical Requirements for Type 1 Tension Control Bolts

<table>
<thead>
<tr>
<th>Element</th>
<th>Heat Analysis</th>
<th>Product Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>0.30 to 0.52</td>
<td>0.28 to 0.55</td>
</tr>
<tr>
<td>Manganese, min</td>
<td>0.60</td>
<td>0.57</td>
</tr>
<tr>
<td>Phosphorus, max</td>
<td>0.040</td>
<td>0.048</td>
</tr>
<tr>
<td>Sulfur, max</td>
<td>0.050</td>
<td>0.058</td>
</tr>
<tr>
<td>Silicon</td>
<td>0.15 to 0.30</td>
<td>0.13 to 0.32</td>
</tr>
<tr>
<td>Boron</td>
<td>See 7.1.5 and 7.1.6</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Element</th>
<th>Product Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>0.30 to 0.52</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.60</td>
</tr>
<tr>
<td>Phosphorus, max</td>
<td>0.040</td>
</tr>
<tr>
<td>Sulfur, max</td>
<td>0.050</td>
</tr>
<tr>
<td>Silicon</td>
<td>0.10 to 0.30</td>
</tr>
<tr>
<td>Boron</td>
<td>0.0005 to 0.003</td>
</tr>
</tbody>
</table>

8.2.4 For bolts on which hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event of controversy over low hardness tests.

8.3 Nuts and Washers—Mechanical properties for nuts and washers shall be in accordance with the applicable specification in 6.6.3.

9. Assembly Lot Tension Test

9.1 Purpose—The assembly lot tension test shall be performed on fastener assemblies to determine the ability of the assembly to provide the required minimum tension.

9.2 Requirement—Full size completed assemblies tested in accordance with 14.4 shall develop a bolt tension when the spline end is separated from the bolt conforming to the requirements in Table 5, Column 1.

10. Dimensions

10.1 Tension Control Bolts:

10.1.1 Tension control bolts shall be furnished with either round (button or dome), heavy hex structural or alternate design heads; as specified by the purchaser.

10.1.2 The tension control bolts shall have a body conforming to the dimensions for heavy hex structural bolts specified in ANSI B18.2.1 and a spline end conforming to the dimensions in Fig. 1.

10.1.3 Head designs as specified in 10.1.1 shall have a bearing surface area and head height equal to or larger than required for heavy hex structural bolts in ANSI B18.2.1.

10.1.4 Round heads shall conform to the dimensions in Fig. 1.

10.1.5 The thread length shall be as specified in ANSI B18.2.1 for heavy hex structural bolts.

10.2 Nuts and Washers—The dimensions for nuts and washers shall be in accordance with the applicable specification specified in 6.6.3.

10.3 Threads:

10.3.1 Threads on tension control bolts shall be the Unified Coarse Thread Series as specified in ASME B1.1, and shall have Class 2A tolerances.

10.3.2 Unless otherwise specified, zinc coated tension control bolts to be used with nuts which have been tapped oversize in accordance with Specification A 563, shall have Class 2A threads before mechanically deposited zinc coating.

10.3.3 The gaging limit for bolts shall be verified during manufacture. In case of purchaser/supplier controversy over thread compliance, System 21 of ASME B18.18.3M shall be used for referee purposes.

11. Workmanship, Finish, and Appearance

11.1 Surface discontinuity limits for tension control bolts, inspection, and evaluation of the surface discontinuities, quench cracks, forging cracks, head bursts, shear bursts, seams, folds, thread laps, voids, tool marks, nicks, and gouges shall be in accordance with Specification F 788/F 788M (see Note 3).

Note 3—Specifications F 788/F 788M and F 1470 do not guarantee 100 % freedom from head bursts. Sampling is designed to provide a 95 % confidence level of freedom from head bursts in any test lot. Head bursts, within the limits in Specification F 788/F 788M, are unsightly but do not affect mechanical properties or functional requirements of the bolt.
11.2 Surface discontinuity limits for the nut component shall be in accordance with the applicable specification specified in 6.6.3.

12. Visual Inspection for Head Bursts

12.1 Requirements—Each bolt component lot shall be visually inspected for head bursts in accordance with the sample size and acceptance values specified in 13.5.6 and shall conform to the requirements in 12.3. Samples shall be taken at random.

12.2 Burst Definition—A burst is an open break in the metal (material). Bursts can occur on the periphery of the round head or on the flats or corners of hex heads.

12.3 Defective Criteria:

12.3.1 Round Heads—Head bursts shall be evaluated in accordance with the provisions stated in Specification F 788/F 788M for products with circular heads.

12.3.2 Hex Heads—Any bolt that contains a burst in the flat of the head that extends into the top crown surface of the head (chamfer circle) or the under-head bearing surface shall be a defective bolt. Head bursts shall be evaluated in accordance with the provisions stated in Specification F 788/F 788M for hex head product.

12.3.3 Alternate Design Heads—Any tension control bolt having bursts as specified in 12.3.1 through 12.3.2, as applicable to the head configuration shall be rejected.

13. Testing

13.1 Testing Responsibility:

### TABLE 2 Chemical Requirements for Type 3 Tension Control Bolts

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Analysis</td>
<td>0.33 to 0.40</td>
<td>0.38 to 0.48</td>
<td>0.15 to 0.25</td>
<td>0.15 to 0.25</td>
<td>0.20 to 0.25</td>
<td>0.20 to 0.25</td>
</tr>
<tr>
<td>Product Analysis</td>
<td>0.31 to 0.42</td>
<td>0.36 to 0.50</td>
<td>0.14 to 0.26</td>
<td>0.14 to 0.26</td>
<td>0.18 to 0.27</td>
<td>0.19 to 0.26</td>
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<tr>
<td>Manganese:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Analysis</td>
<td>0.90 to 1.20</td>
<td>0.70 to 0.90</td>
<td>0.80 to 1.35</td>
<td>0.40 to 1.20</td>
<td>0.60 to 1.00</td>
<td>0.90 to 1.20</td>
</tr>
<tr>
<td>Product Analysis</td>
<td>0.86 to 1.24</td>
<td>0.67 to 0.93</td>
<td>0.76 to 1.39</td>
<td>0.36 to 1.24</td>
<td>0.56 to 1.04</td>
<td>0.86 to 1.24</td>
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<tr>
<td>Phosphorus:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Analysis</td>
<td>0.040 max</td>
<td>0.06 to 0.12</td>
<td>0.035 max</td>
<td>0.040 max</td>
<td>0.040 max</td>
<td>0.040 max</td>
</tr>
<tr>
<td>Product Analysis</td>
<td>0.045 max</td>
<td>0.06 to 0.125</td>
<td>0.040 max</td>
<td>0.055 max</td>
<td>0.045 max</td>
<td>0.045 max</td>
</tr>
<tr>
<td>Sulfur:</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Analysis</td>
<td>0.050 max</td>
<td>0.050 max</td>
<td>0.040 max</td>
<td>0.050 max</td>
<td>0.040 max</td>
<td>0.040 max</td>
</tr>
<tr>
<td>Product Analysis</td>
<td>0.055 max</td>
<td>0.055 max</td>
<td>0.045 max</td>
<td>0.050 max</td>
<td>0.045 max</td>
<td>0.045 max</td>
</tr>
<tr>
<td>Silicon:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Analysis</td>
<td>0.15 to 0.35</td>
<td>0.30 to 0.50</td>
<td>0.15 to 0.35</td>
<td>0.25 to 0.50</td>
<td>0.15 to 0.35</td>
<td>0.15 to 0.35</td>
</tr>
<tr>
<td>Product Analysis</td>
<td>0.13 to 0.37</td>
<td>0.25 to 0.55</td>
<td>0.13 to 0.37</td>
<td>0.20 to 0.55</td>
<td>0.13 to 0.37</td>
<td>0.13 to 0.37</td>
</tr>
<tr>
<td>Nickel:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Analysis</td>
<td>0.25 to 0.45</td>
<td>0.50 to 0.80</td>
<td>0.25 to 0.50</td>
<td>0.50 to 0.80</td>
<td>0.30 to 0.60</td>
<td>0.20 to 0.40</td>
</tr>
<tr>
<td>Product Analysis</td>
<td>0.22 to 0.48</td>
<td>0.47 to 0.83</td>
<td>0.22 to 0.53</td>
<td>0.47 to 0.83</td>
<td>0.27 to 0.63</td>
<td>0.17 to 0.43</td>
</tr>
<tr>
<td>Copper:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Analysis</td>
<td>0.25 to 0.45</td>
<td>0.20 to 0.40</td>
<td>0.20 to 0.50</td>
<td>0.30 to 0.50</td>
<td>0.30 to 0.60</td>
<td>0.20 to 0.40</td>
</tr>
<tr>
<td>Product Analysis</td>
<td>0.22 to 0.48</td>
<td>0.17 to 0.43</td>
<td>0.17 to 0.53</td>
<td>0.27 to 0.53</td>
<td>0.27 to 0.63</td>
<td>0.17 to 0.43</td>
</tr>
<tr>
<td>Chromium:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Analysis</td>
<td>0.45 to 0.65</td>
<td>0.50 to 0.75</td>
<td>0.30 to 0.50</td>
<td>0.50 to 1.00</td>
<td>0.60 to 0.90</td>
<td>0.45 to 0.65</td>
</tr>
<tr>
<td>Product Analysis</td>
<td>0.42 to 0.68</td>
<td>0.47 to 0.83</td>
<td>0.27 to 0.53</td>
<td>0.45 to 1.05</td>
<td>0.55 to 0.95</td>
<td>0.42 to 0.68</td>
</tr>
<tr>
<td>Vanadium:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Analysis</td>
<td>a</td>
<td>a</td>
<td>0.020 min</td>
<td>a</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>Product Analysis</td>
<td>a</td>
<td>a</td>
<td>0.010 min</td>
<td>a</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>Molybdenum:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Analysis</td>
<td>a</td>
<td>0.06 max</td>
<td>b</td>
<td>0.10 max</td>
<td>b</td>
<td>b</td>
</tr>
<tr>
<td>Product Analysis</td>
<td>a</td>
<td>0.07 max</td>
<td>b</td>
<td>0.11 max</td>
<td>b</td>
<td>b</td>
</tr>
<tr>
<td>Titanium:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Analysis</td>
<td>a</td>
<td>a</td>
<td>b</td>
<td>0.05 max</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>Product Analysis</td>
<td>a</td>
<td>a</td>
<td>b</td>
<td>a</td>
<td>b</td>
<td>b</td>
</tr>
</tbody>
</table>

A Designations A, B, C, D, E, and F are classes of material used for Type 3 tension control bolts. Selection of a class shall be at the option of the bolt manufacturer.

* These elements are not specified or required. They shall be present only as residuals.

### TABLE 3 Hardness Requirements for Tension Control Bolts

<table>
<thead>
<tr>
<th>Bolt Size in.</th>
<th>Bolt Length, in.</th>
<th>Brinell</th>
<th>Rockwell C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 to 1 in., incl</td>
<td>Less than 3D</td>
<td>253</td>
<td>319</td>
</tr>
<tr>
<td></td>
<td>3D and over</td>
<td>. . .</td>
<td>319</td>
</tr>
<tr>
<td>1 1/8 in.</td>
<td>Less than 3D</td>
<td>223</td>
<td>286</td>
</tr>
<tr>
<td></td>
<td>3D and over</td>
<td>. . .</td>
<td>286</td>
</tr>
</tbody>
</table>

A Bolts having a length less than three times the diameter, see 8.2.3.

D = Nominal diameter or thread size.

11.2 Surface discontinuity limits for the nut component shall be in accordance with the applicable specification specified in 6.6.3.

12. Visual Inspection for Head Bursts

12.1 Requirements—Each bolt component lot shall be visually inspected for head bursts in accordance with the sample size and acceptance values specified in 13.5.6 and shall conform to the requirements in 12.3. Samples shall be taken at random.
13.1.1 Each component lot and assembly lot shall be tested by the manufacturer prior to shipment in accordance with the lot identification control quality assurance plan in 13.2 through 13.5.

13.1.2 When components or assemblies are furnished by a source other than the manufacturer, the responsible party as defined in Section 18 shall be responsible for assuring all tests have been performed and the components and assemblies comply with the requirements of this specification.

13.2 Purpose of Lot Inspection—The purpose of a lot inspection program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective it is essential that secondary processors, distributors, and purchasers maintain the identification and integrity of each lot until the assemblies are installed.

13.3 Lot Control—All components shall be manufactured, processed, and tested in accordance with a lot control plan that provides lot purity and lot identification. The manufacturer, secondary processors, and distributors shall identify and maintain the integrity of each lot of components and finished assemblies from raw material selection through all processing operations and treatments to final packing and shipment. Each component lot shall be assigned its own component lot number and each assembly lot its own assembly lot number.

13.4 Lot Definition—Component lots and assembly lots shall be defined as specified in Section 3.

13.5 Number of Tests:

13.5.1 Tensile strength, proof load, and hardness sampling shall be in accordance with Guide F 1470.

13.5.2 Chemical composition sampling shall be one test per heat using either the heat or product analysis method.

13.5.3 Assembly lot tension test sample size shall be in accordance with Guide F 1470, Sample Level C, Table 3, as a minimum.

13.5.4 Coating Thickness sampling shall be in accordance with Guide F 1470.

13.5.5 Dimensional and thread fit sampling shall be in accordance with the manufacturer’s standard quality control practices. In the event of dispute, acceptance shall be based on the requirements for Final Inspection-Non Destructive shown in ANSI B18.18.3M.

13.5.6 Surface discontinuity sampling, including Head Bursts, shall be in accordance with Specification F 788/F 788M.

13.5.7 Sampling for the nut and washer components shall be in accordance with the applicable nut and washer specification referenced in 6.6.3.

13.5.8 When tested in accordance with the required sampling plan, a component lot shall be rejected if any of the test specimens fail to meet the applicable requirements.

### TABLE 4 Tensile Requirements for Full Size Tension Control Bolts

<table>
<thead>
<tr>
<th>Bolt Size, Threads per in. and Series Designation</th>
<th>Stress Area(a) in.(^2)</th>
<th>Tensile Strength(b) lbs, min, lbf</th>
<th>Proof Load Length Measurement Method, lbf</th>
<th>Alternative Proof Load(c) Yield Strength Method min. lbf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column 1</td>
<td>Column 2</td>
<td>Column 3</td>
<td>Column 4</td>
<td>Column 5</td>
</tr>
<tr>
<td>(\frac{1}{2}) in. — 13 UNC</td>
<td>0.142</td>
<td>17 050</td>
<td>12 050</td>
<td>13 050</td>
</tr>
<tr>
<td>(\frac{3}{4}) in. — 11 UNC</td>
<td>0.226</td>
<td>27 100</td>
<td>19 200</td>
<td>20 800</td>
</tr>
<tr>
<td>(\frac{7}{8}) in. — 10 UNC</td>
<td>0.334</td>
<td>40 100</td>
<td>28 400</td>
<td>30 700</td>
</tr>
<tr>
<td>(1) in. — 9 UNC</td>
<td>0.462</td>
<td>55 400</td>
<td>39 250</td>
<td>42 500</td>
</tr>
<tr>
<td>1 (\frac{1}{4}) in. — 8 UNC</td>
<td>0.606</td>
<td>72 700</td>
<td>51 500</td>
<td>55 750</td>
</tr>
<tr>
<td>1 (\frac{1}{4}) in. — 7 UNC</td>
<td>0.763</td>
<td>80 100</td>
<td>56 450</td>
<td>61 800</td>
</tr>
</tbody>
</table>

\(a\) The stress area is calculated as follows:

\[
A_s = 0.7854 [D - (0.9743/n)]^2
\]

where:

\(A_s\) = stress area, in.\(^2\)

\(D\) = nominal bolt size, and

\(n\) = threads per inch.

\(b\) Loads tabulated are based on the following:

<table>
<thead>
<tr>
<th>Bolt Size, in.</th>
<th>Column 3</th>
<th>Column 4</th>
<th>Column 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\frac{1}{2}) to 1, incl.</td>
<td>120 000 psi</td>
<td>85 000 psi</td>
<td>92 000 psi</td>
</tr>
<tr>
<td>(1\frac{1}{8})</td>
<td>105 000 psi</td>
<td>74 000 psi</td>
<td>81 000 psi</td>
</tr>
</tbody>
</table>

\(c\) The manufacturers acceptance test tension values are 5% higher than the tension in Column 2 and are rounded to the nearest 1000 lbs.

\(d\) The values in Column 2 are excerpts from the Research Council Specification for Structural Joints Using ASTM A 325 and A 490 Bolts. They are equal to 70% of the specified minimum tensile strength for tests of full size A 325 bolts with UNC threads tested in axial tension and are rounded to the nearest 1000 pounds (kips).

### TABLE 5 Assembly Lot Tension Test Requirements

<table>
<thead>
<tr>
<th>Bolt Size, in. and Series Designation</th>
<th>Manufacturers Acceptance Test Tension, lbf</th>
<th>Acceptance Test Tension, lbf (For Information Only)(b)</th>
<th>Tension, lbs, minA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column 1</td>
<td>Column 2</td>
<td>Column 3</td>
<td>Column 4</td>
</tr>
<tr>
<td>(\frac{1}{2}) – 13 UNC</td>
<td>13 000</td>
<td>12 000</td>
<td>12 000</td>
</tr>
<tr>
<td>(\frac{3}{4}) – 11 UNC</td>
<td>20 000</td>
<td>19 000</td>
<td>19 000</td>
</tr>
<tr>
<td>(\frac{7}{8}) – 10 UNC</td>
<td>29 000</td>
<td>28 000</td>
<td>28 000</td>
</tr>
<tr>
<td>(1) – 9 UNC</td>
<td>41 000</td>
<td>39 000</td>
<td>39 000</td>
</tr>
<tr>
<td>(1\frac{1}{8}) – 8 UNC</td>
<td>54 000</td>
<td>51 000</td>
<td>51 000</td>
</tr>
<tr>
<td>1 (\frac{1}{4}) – 7 UNC</td>
<td>59 000</td>
<td>56 000</td>
<td>56 000</td>
</tr>
</tbody>
</table>

\(A\) The manufacturers acceptance test tension values are 5% higher than the tension in Column 2 and are rounded to the nearest 1000 lbs.

\(b\) The values in Column 2 are excerpts from the Research Council Specification for Structural Joints Using ASTM A 325 and A 490 Bolts. They are equal to 70% of the specified minimum tensile strength for tests of full size A 325 bolts with UNC threads tested in axial tension and are rounded to the nearest 1000 pounds (kips).
14. Test Methods
14.1 Perform chemical analyses in accordance with Test Methods, Practices, and Terminology A 751.
14.2 Tensile and Hardness—Conduct tensile and hardness tests in accordance with Test Methods F 606 using the wedge tension testing of full size product method to determine full size tensile strength.
14.3 Proof Load—Conduct proof load tests in accordance with Test Methods F 606 Method 1, Length Measurement, or Method 2, Yield Strength: at the option of the manufacturer.
14.4 Assembly Installation Tension Test:
14.4.1 Test Conditions—Conduct tests at an ambient temperature between 50° and 90° F (10 and 32°C).
14.4.2 Test Device:
14.4.2.1 The tension measuring device shall be capable of measuring the assembly tension after torquing.
14.4.2.2 The tension measuring device shall be calibrated in 1000 lb (454 kg) increments.
14.4.2.3 Calibrate the tension measuring device (and any other equipment) based on the frequency of use and the equipment manufacturers recommendation, but not less than one time per year.
14.4.3 Installation and Tension Test:
14.4.3.1 Install the tension control bolt, nut, washer, and appropriate spacer washer(s) in the tension measuring device. The device shall not restrain the head from turning.
14.4.3.2 Install the washer(s) under the nut such that three to five threads of the bolt are located between the bearing face of the nut and the underside of the bolt head using the washer furnished with the assembly in contact with the nut.
14.4.3.3 Initially tighten the assembly using a hand wrench by turning the nut to produce the setting tension specified below.
14.4.3.4 Complete tightening the assembly nut using a spline drive installation tool capable of engaging the nut and spline end simultaneously during this process. Tighten continuously until the spline shears from the bolt.
14.4.3.5 The bolt component, regardless of head style, shall not be restrained during the assembly tightening.
14.4.3.6 In order to pass, shearing of the spline end shall occur in the shear groove. Failure in the threaded region shall be considered nonconforming.
14.4.3.7 Record the tension after shearing of the spline end as the assembly installation tension.

<table>
<thead>
<tr>
<th>Bolt Diameter, in.</th>
<th>Setting Tension</th>
<th>Tension, 1000 lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>1 to 3</td>
<td></td>
</tr>
<tr>
<td>5/8</td>
<td>2 to 4</td>
<td></td>
</tr>
<tr>
<td>3/4</td>
<td>3 to 5</td>
<td></td>
</tr>
<tr>
<td>7/8</td>
<td>4 to 6</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5 to 7</td>
<td></td>
</tr>
<tr>
<td>1 1/2</td>
<td>6 to 8</td>
<td></td>
</tr>
</tbody>
</table>

15. Inspection
15.1 If the inspection described in 15.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.
15.2 The purchaser’s quality assurance representative shall have free entry to all parts of the manufacturer’s works or suppliers place of business, that concern the manufacture or supply of the assemblies. The manufacturer or supplier shall afford the purchaser’s quality assurance representative all reasonable facilities to satisfy him that the assemblies are being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser’s representative shall be made before shipment, and shall be conducted so as not to interfere unnecessarily with the operation of the manufacturers or suppliers operations.

16. Rejection and Rehearing
16.1 Disposition of nonconforming sets shall be in accordance with Guide F 1470 the section titled “Disposition of Nonconforming Lots.”

17. Certification
17.1 The manufacturer or supplier, whichever is the responsible party as defined in Section 18, shall furnish the purchaser a test report for each lot that includes the following:
17.1.1 Heat analysis and heat number of each component (bolt, nut and washer), and a statement certifying that heats having the elements listed in 7.1.4 and 7.1.5 intentionally added were not used to produce the tension control bolts.
17.1.2 Results of hardness, tensile and proof load tests of each component (bolt, nut and washer),
17.1.3 Results of Assembly Lot Installation Tension Tests—At the manufacturers option the mean and standard deviations may be reported,
17.1.4 Results of zinc coating thickness measurements,
17.1.5 Results of visual inspection for bursts,
17.1.6 Statement of compliance with dimensional and thread fit requirements,
17.1.7 Assembly lot number, individual component lot numbers for bolt-nut-washer, and purchase order number,
17.1.8 ASTM specification number, type, and issue date,
17.1.9 Complete mailing address of responsible party, and
17.1.10 Title and signature of the individual assigned certification responsibility by the company officers.

17.2 Failure to include all the required information on the test report shall be cause for rejection.

18. Responsibility
18.1 The party responsible for the assemblies shall be the organization that supplies the assemblies to the purchaser and certifies that the assemblies have been manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

19. Product Marking
19.1 Manufacturers Identification—All components of each assembly shall be marked by the manufacturer with a unique identifier to identify the manufacturer.
19.2 Grade Identification:
19.2.1 Type 1 tension control bolts shall be marked “A325TC,” and at the manufacturer’s option, with three radial lines 120° apart.
19.2.2 Type 3 tension control bolts shall be marked “A325TC” with all characters underlined. Manufacturers shall be permitted to use additional marks indicating the bolt is a weathering type.
19.3 Marking Location and Methods—All markings shall be located on the top of the bolt head and shall be raised or depressed at the manufacturers option. The nut and washer marking shall be depressed.

19.4 Acceptance Criteria—Tension control bolts which are not marked in accordance with these provisions shall be considered nonconforming and subject to rejection.

20. Packaging and Package Marking

20.1 Packaging:
20.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.
20.1.2 All product shall be assembled.
20.1.3 When special packaging requirements are required they shall be defined at the time of the inquiry and order.
20.2 Package Marking:

20.2.1 Each shipping unit shall include or be plainly marked with the following information:
20.2.1.1 ASTM designation and type,
20.2.1.2 Size, nominal diameter and length,
20.2.1.3 Name of the manufacturer; and the supplier, if furnished by an entity other than the manufacturer,
20.2.1.4 Number of assemblies,
20.2.1.5 Assembly lot number (s),
20.2.1.6 Purchase order number (s), and
20.2.1.7 Country of origin.

21. Keywords

21.1 alternate design fasteners; bolts; carbon steel; fasteners; spline end; structural; tension control bolt; tension control bolt assembly; twist-off bolt; weathering steel

SUMMARY OF CHANGES

Committee F16 has identified the location of selected changes to this standard since the last issue, F 1852–02, that impact the use of this standard. (Approved Jan. 1, 2004.)

(1) Deleted old Section 1.5.
(2) Added new Section 1.5 that references Terminology F 1789 for definitions of terms.
(3) Revised Section 11.1 to include a note recognizing that Specification F 788/F 788M nor Specification F 1470 guarantee 100 % freedom from head burst.

Committee F16 has identified the location of selected changes to this standard since the last issue, F 1852–00, that impact the use of this standard. (Approved Dec. 10, 2002.)

(1) In Table 4, corrected the stress area for the 5/8 – 11 UNC bolt size from 0.266 to 0.226.

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Standard Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners

This standard is issued under the fixed designation F 1940; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers a procedure to prevent, to the extent possible, internal hydrogen embrittlement (IHE) of fasteners by monitoring the plating or coating process, such as those described in Specifications F 1137 and F 1941. The process is quantitatively monitored on a periodic basis with a minimum number of specimens as compared to qualifying each lot of fasteners being plated or coated. Trend analysis is used to ensure quality as compared to statistical sampling analysis of each lot of fasteners. This test method consists of a mechanical test for the evaluation and control of the potential for IHE that may arise from various sources of hydrogen in a plating or coating process.

1.2 This test method applies to externally threaded tensile fasteners that can also be loaded in bending during installation.

1.3 This test method is limited to evaluating hydrogen induced embrittlement due only to processing (IHE) and not due to environmental exposure (EHE, see Test Method F 1624).

1.4 This test method is not intended to measure the relative susceptibility of steels to either IHE or EHE.

1.5 This test method is limited to ferrous fasteners that are susceptible to time-delayed fracture caused by the diffusion of hydrogen under stress.

1.6 This test method uses a notched square bar specimen that conforms to Test Method F 519, Type 1e, except that the radius is increased to accommodate the deposition of a larger range of platings and coatings. For the background on Test Method F 519 testing, see publications ASTM STP 543 and ASTM STP 962. The stress concentration factor is at a $K_t = 3.1 \pm 0.2$. The sensitivity is demonstrated with a constant imposed cathodic potential to control the amount of hydrogen. Both the sensitivity and the baseline for residual hydrogen will be established with tests on bare metal specimens in air.

1.7 The sensitivity of each lot of specimens to IHE shall be demonstrated. A specimen made of AISI E4340 steel heat treated to a hardness range of 50 to 52 HRC is used to produce a “worst case” condition and maximize sensitivity to IHE.

1.8 A notched four-point bend specimen undergoes sustained load and slow strain rate testing by using incremental loads and hold times under displacement control to measure a threshold stress in an accelerated manner in accordance with Test Method F 1624. The test is an accelerated ($=24$ h) incrementally increasing step load test method that measures the threshold for hydrogen stress cracking that is used to quantify the amount of residual hydrogen in the specimen.

1.9 In this test method, bending is used instead of tension because it produces the maximum local limit load tensile stress in a notched bar of up to 2.3 times the yield strength as measured in accordance with Test Method E 8. A fastener that is unintentionally exposed to bending on installation may attain this maximum local tensile stress.

1.10 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.11 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

D 1193 Specification for Reagent Water
E 4 Practices for Force Verifications of Testing Machines
E 8 Test Methods for Tension Testing of Metallic Materials
E 18 Test Methods of Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

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1 This test method is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.93 on Quality Assurance Provisions for Fasteners.
5 Annual Book of ASTM Standards, Vol 03.01.
3.1 Terms and Symbols Specific to This Standard:

3.1.1 environmental hydrogen embrittlement (EHE)—test conducted in a specified environment—embrittlement caused by hydrogen introduced into steel from external sources.

3.1.2 internal hydrogen embrittlement (IHE)—test conducted in air—embrittlement caused by residual hydrogen from processing

3.1.3 $\text{ISL}_{\text{B}}$—threshold from an incremental step load test on a plated or processed specimen.

3.1.4 NFS(B)—notched fracture strength in air of a bare specimen in bending at loading rates of 50 to 250 ksi/min (350 to 1700 MPa/min).

3.1.5 NFS(B)$_{F_{1624}}$—notched fracture strength in air of a bare specimen in bending at Test Method F 1624 step loading rates.

3.1.6 process—a defined event or sequence of events that may include pretreatments, plating, or coating and posttreatments that are being evaluated or qualified.

3.1.7 threshold—the maximum load at the onset of cracking that is identified by a 5 % drop in load of NFS(B)$_{F_{1624}}$ under displacement control.

4. Summary of Test Method

4.1 Specimens of fixed geometry, certified to have been heat treated to a hardness range of 50 to 52 HRC, and which have been certified to exhibit sensitivity to embrittlement from trace amounts of residual hydrogen in steel, are processed with actual parts.

4.2 An unstressed test specimen is processed in accordance with the plating or coating process being qualified. The specimen is then tested under incremental step load to measure the threshold stress. The loading rate must be slow enough to ensure that the threshold stress will be detected if deleterious amounts of hydrogen are present in “worst case” sensitized specimens. Loading rate protocols are defined in 9.2 and Test Method F 1624.

4.3 If the threshold in air of the specimen is $\geq$75 % NFS(B)$_{F_{1624}}$, then the process is considered as to not produce sufficient hydrogen to induce time delayed IHE failures in the plated or coated fasteners. See 9.3 for optional limits.

4.4 If the threshold in air of the specimen is <75 % NFS(B)$_{F_{1624}}$, then the process is considered potentially embrittling. Actual fasteners made with steel having a hardness lower than that of the square bar specimen have more tolerance for residual hydrogen because of the process. Therefore, threshold requirements must be adjusted based upon the correlation between the specimen fracture strength NFS(B)$_{F_{1624}}$ and actual fastener hardness. An example of this adjustment is presented in Appendix X1.

5. Significance and Use

5.1 This test method establishes a means to verify the prevention, to the extent possible, of IHE in steel fasteners during manufacture by maintaining strict controls during production operations such as surface preparation, pretreatments, and plating or coating. It is intended to be used as a qualification test for new or revised plating or coating processes and as a periodic inspection audit for the control of a plating or coating process.

5.2 Passing this test allows fasteners to be stressed in tension to the minimum specified tensile load in air with almost no possibility of time delayed fracture in air as a result of IHE from processing. If the amount of residual hydrogen is not sufficient to induce cracking or fracture in the specimen under worst case conditions, then it can be concluded that all of the lots of fasteners processed during that period will not have sufficient residual hydrogen from processing to induce hydrogen embrittlement of the fasteners under stress in air if the process remains in control, unchanged and stable.

5.3 If certified specimens with demonstrated sensitivity to IHE, processed with the fasteners, have a threshold $\geq$75 % of the incremental step load notched bend fracture stress, NFS(B)$_{F_{1624}}$, it is assumed that all fasteners processed the same way during the period will also pass any sustained load IHE test.

6. Apparatus

6.1 Testing Machine—A computerized, four-point bend, digital displacement controlled loading frame that is capable of holding 0.5 % of the NFS(B) and is programmed to increase incrementally in steps of load and time to vary the effective strain rate at the root of the notch between $10^{-5}$ and $10^{-8}$ s$^{-1}$ is required to conduct these tests. Testing machines shall be
within the guidelines of calibration, force range, resolution, and verification of Practice E 4.

6.2 Gripping Devices—Pin-loading devices consistent with Test Method E 399 four-point bend fixtures shall be used to transmit the measured load applied by the testing machine to the test specimen.

6.3 Potentiostatic Control—For verification testing of the sensitivity of the specimens to residual hydrogen from processing, an inert container and potentiostat shall be used to impose a cathodic potential on the specimen. The cathodic charging potential of the specimen can be controlled with a reference saturated calomel electrode (SCE) or equivalent reference electrode such as with A/AgCl in accordance with Practice G 5.

Note 1—A loading device that meets the displacement control step load test requirements and the potentiostatic control requirements of Test Method F 1624 and Test Method F 519 is available.

7. Materials and Reagents

7.1 Materials—UNS G43406 (AISI E 4340) in accordance with AMS 6415.

7.2 Reagents:
7.2.1 Corrosion preventive compound, meeting requirements of AMS 3078.

7.2.2 Solution of reagent water in accordance with Specification D 1193 Type IV, and 3.5 % reagent grade NaCl.

8. Test Specimen

8.1 The test specimen shall be a 0.4W-notched square bar bend specimen: 0.4W-SqB(B), as shown in Fig. 1.

8.2 The notch shall be in the LS orientation in accordance with Terminology E 1823.

8.3 The stress concentration factor for the specimen is $K_t = 3.1 \pm 0.2$.

Note 2—For the relationship between geometry and $K_t$, see Stress Concentration Factors.11

8.4 Manufacture:

8.4.1 The test specimen blanks shall be heat treated in accordance with AMS 2759 to meet the hardness requirement of 50 to 52 HRC in accordance with Test Methods E 18. Rounding in accordance with Practice E 29 permits an absolute hardness range of 49.6 to 52.5 HRC. The hardness shall be determined by the average of three measurements made approximately midway between the notch and the end of the specimen.

8.4.2 The surface finish of all notches shall be finished with a tool capable of attaining a surface roughness of 16 RMS or better. The other surfaces shall have a finish of 32 RMS or better.

8.4.3 All dimensions except for the length shall be produced after quenching and tempering to final hardness. The 0.40-in. (10-mm) dimension shall be produced by low stress grinding. The notch shall be rough machined by wire EDM to within 0.020 in. (0.5 mm) of the final notch depth and low stress ground to the final depth. No chemical or mechanical cleaning shall be allowed after final machining.

8.4.4 Straightening after final heat treatment before machining is prohibited.

8.5 Storage—Before plating or coating, all specimens shall be protected during storage to prevent corrosion. A suitable means of protection is to coat the specimen with a corrosion preventive compound meeting the requirements of ASTM 3078.

8.6 Inspection:

8.6.1 A lot shall consist of only those specimens cut from the same heat of steel in the same orientation, heat treated in the same furnace, quenched and tempered together, and subjected to the same manufacturing processes.

8.6.2 One transverse section shall be microstructurally examined to ensure that if any orientation effects exist, the notch will be in the LS orientation in accordance with Terminology E 1823.

8.6.3 All notched square bar bend specimens shall be considered suitable for test purposes if the sampling and inspection results conform to the requirements of Table 1.

8.6.4 The notched bend fracture strength, NFS(B), of bare specimens is measured in air in four-point bending under displacement control at loading rates of 50 to 250 ksi/min (350 to 1700 MPa/min). The rupture load is used as a measure of strength.

8.7 Sensitivity Test:

8.7.1 The sensitivity to IHE must be demonstrated for each lot of specimens by exposing three trial specimens in air and three trial specimens in an embrittling environmental after manufacture and inspection in accordance with 8.4 through 8.6. The specimens tested shall be representative of the lot.

8.7.2 Sensitivity Specimen Preparation:

8.7.2.1 Ultrasonically clean in acetone for 5 to 10 min to remove the corrosion preventive compound and oils/dirt.

8.7.2.2 Do not acid clean.

8.7.3 Based on the loading profile schedule in Table 2, the requirements for sensitivity of the heat-treated lot of specimens shall be demonstrated if bare specimens fracture in less than 5 h at an imposed potential of −1.2 V versus SCE in a 3.5 % NaCl solution and no delayed fracture occurs in less than 14 h at an imposed potential of −1.2 V versus SCE in a 3.5 % NaCl solution. The specimens, as received, shall be processed and qualified with the fasteners. It is important that the specimens be exposed to the same process as the fasteners for the test to be a valid. Even if the fasteners do not require a degreasing and cleaning process before plating or coating, the specimens shall be degreased to remove the corrosion preventive compound and cleaned in acetone and then placed in the process with the fasteners. An application guideline, to be used as a template for the use of this test method, is provided in Appendix X2.

8.7.4 The average of the results of the three bare specimens tested in air shall be used as the baseline notched fracture strength, NFS(B) [1624-].

8.8 Certification:

8.8.1 Each lot of specimens manufactured shall be certified to indicate that it meets the conditions found in this section, including the following information:

8.8.1.1 Manufacturer of specimen lot.

8.8.1.2 Traceability to raw material, heat treatment, manufacturing, and inspection.

8.8.1.3 Test results for requirements in Table 1 and Table 3.


9.1 Testing Protocol:

9.1.1 Specimen Preparation—The specimens, as received, shall be processed and qualified with the fasteners. It is important that the specimens be exposed to the same process as the fasteners for the test to be valid. Even if the fasteners do not require a degreasing and cleaning process before plating or coating, the specimens shall be degreased to remove the corrosion preventive compound and cleaned in acetone and then placed in the process with the fasteners. An application guideline, to be used as a template for the use of this test method, is provided in Appendix X2.

9.1.2 Number—One or more specimens per process per inspection period shall be used.

9.1.3 Test specimens shall be processed once. Stripping and reuse of specimens is prohibited.

9.1.4 The nominal print dimensions from Fig. 1 of the bare metal specimens shall be used in all calculations.

9.1.5 The specimens shall be in the LS orientation with the notch loaded in tension.

9.2 Load—Incremental step loads and hold times under displacement control shall be used to detect the onset of subcritical crack growth or threshold that is used to quantify the amount of residual hydrogen in a specimen.

9.2.1 A specific incremental step load and holding time protocol in accordance with Test Method F 1624 is prescribed. Instrumented testing equipment with adjustable constant displacement loading is required as described in Test Method F 1624.

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### TABLE 1 Lot Acceptance Criteria for 0.4W-Notched Square Bar Bend Specimens

<table>
<thead>
<tr>
<th>Item</th>
<th>Sampling of Each Lot</th>
<th>Requirement/Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness [4]</td>
<td>5 %</td>
<td>50 to 52 HRC in accordance with Test Method E 18. Round the average of three readings per specimen in accordance with Practice E 29.</td>
</tr>
<tr>
<td>Dimensions</td>
<td>100 %</td>
<td>Meet tolerances of corresponding drawings. Notch dimension verified with shadow graphic projection at 50 to 100 %.</td>
</tr>
<tr>
<td>Notched Fracture strength in bending, NFS(B)</td>
<td>10 ea</td>
<td>NFS(B) of each specimen must be within ±5 % of the average.</td>
</tr>
</tbody>
</table>

---

### TABLE 2 Minimum Step-Loading Profile Requirements for Accelerated (< 24h) Incremental Step Load Sensitivity Tests

<table>
<thead>
<tr>
<th>%NFS(B)</th>
<th>h</th>
<th>%NFS(B)</th>
<th>h</th>
<th>%NFS(B)</th>
<th>h</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1</td>
<td>65</td>
<td>1</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
<td>70</td>
<td>1</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>30</td>
<td>1</td>
<td>75</td>
<td>1</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>40</td>
<td>1</td>
<td>80</td>
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<td>11</td>
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<td>50</td>
<td>1</td>
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<td>55</td>
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<td>60</td>
<td>1</td>
<td>86</td>
<td>1</td>
<td>14</td>
<td>1</td>
</tr>
</tbody>
</table>

### TABLE 3 Sensitivity Test Requirements of Specimens

<table>
<thead>
<tr>
<th>Requirement/Method</th>
<th>Each specimen tested shall have threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare in air</td>
<td>≥85 % of the average notched bend fracture strength, NFS(B) (Table 1)</td>
</tr>
<tr>
<td>Bare at potential of −1.2 V versus SCE in 3.5 % NaCl solution in Spec-</td>
<td>≤50 % of the average notched bend fracture strength NFS(B) (Table 1)</td>
</tr>
<tr>
<td>ification D 1193 Type IV reagent water</td>
<td></td>
</tr>
</tbody>
</table>
9.2.2 ISLo — To measure the threshold of a plated 0.4W-SqB(B) specimen, the plated notch bend specimens are tested in air in four-point bending under displacement control at Test Method F 1624 loading rates (see Table 4). The threshold is the maximum load at the onset of subcritical crack growth at that displacement and corresponding load. The load measured at the constant displacement recorded before the 5 % load drop is recorded as the threshold for that specimen. If the specimen fractures while attempting to reach a new displacement and corresponding higher load, the previous load is recorded. The test results are recorded as a threshold, which is a percentage of the notched fracture stress for that specimen configuration, and not as pass/fail as with the sustained load test, time-to-fracture criterion.

9.2.4 Time can be used as a criterion for achieving a threshold. As an example, specimens achieve a ≥76 % NFS(B) F 1624 when no delayed fracture occurs in less than 12 h, in accordance with Table 4.

9.3 Optional Limits:

9.3.1 Since embrittlement related to hydrogen content varies with hardness, actual fasteners made of low-strength steel might have more tolerance for residual hydrogen because of the process and might not need the rigorous requirement set forth in this standard for threshold. Therefore, adjustments in threshold requirements can be made once a correlation is established. As an example, a threshold of less than 75 % of the fracture strength that is not necessarily hydrogen free can be considered adequate for many applications of lower strength steels.

9.3.2 To obtain a correlation between actual production fasteners and threshold levels in this standard, the threshold level or hydrogen tolerance level for the production fasteners can be measured using Test Method F 1624. An example of an adjustment to the threshold is shown in Appendix X1.

10. Interpretation of Results

10.1 When test specimens exceed 75 % of NFS(B) F 1624 or ≥12 h, the plating bath is considered to be nonembrittling.

10.2 If any test results are marginal or suspect, the actual product lot can be tested in accordance with Test Method F 1624 to determine if the threshold of the actual fastener is ≥90 % of the bend ultimate strength of the fastener.

10.3 Rupture load and net tensile stress for the four-point bend specimens are correlated using the equation \( \sigma_{\text{net}} = M_f / I \) for the specimen geometry provided in Fig. 1. The corresponding average rupture load is reported in units of X.XX lbs (Y.Y N) and corresponding net stress in units of X.XX ksi (Y.Y MPa).

10.4 Statistical Process Control:

10.4.1 The sampling or statistical process control plan used to evaluate the process for the prevention of hydrogen embrittlement (IHE) shall be agreed to between the manufacturer and the purchaser.

10.4.2 The >75 % NFS(B) F 1624 threshold used to qualify the process is specified as a minimum value for individual data. If statistical limits are to be applied, they are to be established through agreement between the manufacturer and purchaser.

11. Report

11.1 A test report shall be produced upon completion of testing that bears the following minimum information:

11.1.1 A specimen lot acceptance and sensitivity certification report,

11.1.2 Identification of the process line,

11.1.3 A description of the plating or coating process,

11.1.4 The threshold load, or percent of notched fracture strength or notch bend strength of bare specimens, as appropriate,

11.1.5 The time under load, and

11.1.6 Disposition of the results.

12. Precision and Bias

12.1 Precision — An interlaboratory test program (ASTM Research Report F16–1000) was designed to estimate the precision of the ISL test as it applies to this test method. The experimental results were entirely generated using notched square bar standard test specimens. Two testing modes were used; testing in air (that is, no imposed potential) and testing under potential (for simulated hydrogen charging conditions).

12.1.1 Within Laboratory Study — In this part of the test program, a large number of specimens (minimum 30) were tested in air within 1 laboratory to estimate repeatability within a single laboratory. The time span for testing 30 specimens was approximately 8 weeks. This was due to the length of the test cycle, which can be as long as 24 h. Therefore, to detect any systematic shift in the values generated by the test apparatus, this test was repeated twice in the space of 1 year. The summary results of the study are presented in Table 5.

The term repeatability limit is used as specified in Practice E 177.

<table>
<thead>
<tr>
<th>Study</th>
<th>SOBs Tested</th>
<th>Avg.</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
<th>95 % Repeatability Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study 1</td>
<td>37</td>
<td>219.5</td>
<td>6.52</td>
<td>204.4</td>
<td>232.1</td>
<td>18.26</td>
</tr>
<tr>
<td>Study 2</td>
<td>30</td>
<td>218.5</td>
<td>4.22</td>
<td>210.8</td>
<td>225.9</td>
<td>11.82</td>
</tr>
</tbody>
</table>

Average of study averages, \( \bar{x} = 219.0 \)
Average of study standard deviations, \( s = 5.37 \)

TABLE 5 Within Laboratory Notch Fracture Strength, NFS (Baseline) Summary of Results
Practice E 691.13 The study consisted of testing square bar specimens from four instead of a minimum of six, the study was modeled on Practice E 177. With the exception of the number of participating laboratories, all other aspects of the testing were conducted as specified in Practice E 177. Each laboratory performed five replicate tests for each condition. The precision statistics are presented in Table 6.

<table>
<thead>
<tr>
<th>Imposed Potential</th>
<th>Fracture Strength Average $x^*$</th>
<th>Repeatability Standard Deviation $S_r$</th>
<th>Reproducibility Standard Deviation $S_R$</th>
<th>95% Repeatability Limit $r$</th>
<th>95% Reproducibility Limit $R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.2 V</td>
<td>71.22</td>
<td>9.88</td>
<td>9.88</td>
<td>27.66</td>
<td>27.66</td>
</tr>
<tr>
<td>-1.0 V</td>
<td>85.12</td>
<td>9.70</td>
<td>9.70</td>
<td>27.15</td>
<td>27.15</td>
</tr>
<tr>
<td>-0.9 V</td>
<td>102.97</td>
<td>10.02</td>
<td>10.02</td>
<td>28.06</td>
<td>28.06</td>
</tr>
<tr>
<td>-0.8 V</td>
<td>179.33</td>
<td>9.77</td>
<td>12.44</td>
<td>27.35</td>
<td>34.83</td>
</tr>
<tr>
<td>AIR</td>
<td>221.82</td>
<td>5.81</td>
<td>7.16</td>
<td>16.27</td>
<td>20.06</td>
</tr>
</tbody>
</table>

12.1.2 Interlaboratory Study—Four testing facilities each using a single ISL loading frame, participated in the study. With the exception of the number of participating laboratories, four instead of a minimum of six, the study was modeled on Practice E 691. The study consisted of testing square bar specimens at five different conditions, four at different applied potentials, -0.8, -0.9, -1.0, and -1.2 V and one in air. Each laboratory performed five replicate tests for each condition. The precision statistics are presented in Table 6.

The terms repeatability limit and reproducibility limit are used as specified in Practice E 177.

12.2 Bias:

12.2.1 To eliminate any bias of results as a result of variation in the conditions of specimen manufacture, all the specimens used for this study were E4340 notched square bar specimens, obtained from a single controlled production lot, manufactured with minimal variation. Therefore, note that variance within the specimen population, however minimal, was implicitly considered in the precision estimates.

12.2.2 All of the instruments were subject to normal calibration procedures by the equipment manufacturer. Any results obtained through obvious error in procedure or equipment malfunction were disqualified from the study.

12.2.3 This method has no bias because comparative measurement of hydrogen embrittlement is defined only in terms of this test method.

12.2.4 Random lot-to-lot bias in the properties of square bar specimens related to raw material or specimen manufacture may exist. This test method produces a quantitative fractional measure based on the baseline fracture strength of square bar specimens not exposed to hydrogen. Since there is no universally accepted reference or laboratory suitable for determining the bias for square bar specimens, no justifiable statement of bias can be made in relation to the baseline fracture strength of specimens. However, lot-to-lot bias for square bar specimens does not affect the test fractional results provided a baseline fracture strength is established for every lot of square bar specimens.

13. Keywords

13.1 coating; delayed failure; displacement control; EHE; fasteners; hydrogen embrittlement; IHE; incremental step load; loading rate; plating; steel; threshold

APPENDIXES

(Nonmandatory Information)

X1. ALTERNATE SQUARE BAR THRESHOLD DETERMINATION FOR SPECIFIC PRODUCT LOTS

X1.1 Scope

X1.1.1 Since embrittlement related to hydrogen content can vary with hardness, actual fasteners made of low-strength steel might have more tolerance for residual hydrogen because of the process and might not need the rigorous requirement set forth in this standard for threshold. Therefore, adjustments in threshold requirements can be made for a specific lot of fasteners once a correlation is established.

Note X1.1—Note that embrittlement related to hydrogen can also vary with other metallurgical and chemical characteristics of steel and that “low-strength steel” is not always a predictor of more tolerance for residual hydrogen.

X1.1.2 To obtain a correlation between actual production fasteners from singular lots and specimen threshold levels in this standard, the threshold level or hydrogen tolerance level for the production hardware can be measured using four-point bending in accordance with Test Method F 1624 as a function of an applied electrical potential verses a saturated calomel electrode, (SCE) in a 3.5 % sodium chloride solution. An example of four-point bend fixturing used for Test Method F 1624 testing is shown in Fig. X1.1 in which the tensile stress in bending, $\sigma_b$, at the root of the thread can be computed using the following formula:

$$\sigma_b = (32M/\pi D_t^3)$$

(1)

where:

- $D_t =$ minimum thread diameter (inch) and
- $M =$ applied moment (inch-pounds) which $= P_b \times \lambda$.

X1.1.3 Once the threshold for the product has been determined as a function of the applied potential, the percent fracture strength for the measured thresholds at each potential are plotted as shown in Fig. X1.2. A statistical response in the data must be expected, and therefore judgment in defining a region bounded by upper and lower limits is required. Using
actual square bar data generated at the same potentials and this data, the alternate threshold can then be determined.

**X1.2 Alternate Threshold Determination**

X1.2.1 For a specific lot of product, find the potential at which the lower limit of the threshold region intersects the 100 % fracture strength line.

X1.2.2 With this potential find, the corresponding percent fracture strength for the square bar at its upper limit. This fracture strength is the alternate threshold that can be used for this product.

X1.2.3 *Example 1*—For Product Lot A on Fig. X1.2, the potential at which the lower limit of the threshold region intersects the 100 % line is −0.80 V versus SCE. The upper limit for square bar percent fracture strength at this potential is 75 %. This is the threshold specified in this document.

X1.2.4 *Example 2*—For Product Lot B on Fig. X1.2, the potential at which the lower limit of the threshold region intersects the 100 % line is −0.95 V versus SCE. The upper limit for square bar percent fracture strength at this potential is 40 %. For this product, an alternate threshold could be used since this steel is considerably less sensitive to residual hydrogen.
X2. APPLICATION GUIDELINE

X2.1 Scope

X2.1.1 This application guideline is targeted to the general fastener plating and coating industry. It is a tested and viable model, designed to be used as a template for the application of Test Method F 1940. As such, it does not specify any mandatory requirements; however, it should serve as a checklist for anyone who wishes to use the Incremental Step Load (ISL) test method for process verification to prevent hydrogen embrittlement in plated or coated fasteners. Specific testing procedures, sampling schedules, and acceptance criteria should be established based upon the individual characteristics of each process and upon agreement between the purchaser and the supplier.

X2.2 Testing Criteria

X2.2.1 Each individual plating process shall be tested and qualified independently.

X2.2.2 The supplier shall require that the purchaser provide certification of chemical and mechanical properties of the fasteners to be coated. This will allow the supplier to gage the relative susceptibility of the fasteners to internal hydrogen embrittlement (IHE).

X2.2.2.1 Increasing hardness, tensile strength, and carbon content in martensitic steel are the most obvious characteristics that will increase the susceptibility of fasteners to IHE. Consequently, the most susceptible products should be processed on the best-qualified line(s).

X2.2.3 Testing shall be conducted at the highest specified pickling acid concentration and the longest pickling duration for a given line. In the case of an electroplating line, testing shall also be conducted at the highest operational current density in the electroplating cell.

X2.2.4 Statistical process control methodology and criteria can be applied to the test procedure upon agreement between the supplier and the purchaser. Process control or statistical process control must be well documented to establish the stability of the process and the ability to control process parameters and characteristics. The results of this control shall be used in conjunction with the ISL test results as justification for a decrease in testing frequency.

X2.2.5 A minimum of three square bar specimens shall be placed in a single processing unit. A processing unit can be a barrel, a rack, a drum, or a basket depending on the nature of the process being tested. For the sake of simplicity, the processing unit will be referred to as a unit.

X2.2.5.1 The average of the three results within a unit shall represent a single data point for statistical evaluation. Variation within each unit must be within ±10% of the measured average threshold for the group of three specimens. This is a benchmark for the validity of the results within a single unit.

X2.2.6 Variation of results from one unit to the next must be within ±10% of the measured average threshold for the population of units to meet process control objectives.

X2.2.7 If the measured average threshold for any unit is less than 75% of the certified average notched fracture strength NFS(B) of the product, it is recommended that an agreement be reached between the supplier and the purchaser as to the minimum acceptable ISL threshold for processed specimens. The basis for such an agreement should be established through threshold testing of the product. (See 9.3 and Appendix X1.)

X2.3 Sampling Schedule

X2.3.1 Stage 1—Test three specimens in one unit daily for a minimum of one operational week. If variation of the test results remains within the acceptable range, go to Stage 2. If not, testing must continue to determine and eliminate the cause of variation.

X2.3.2 Stage 2—Test three specimens in one unit weekly for a minimum of four weeks. If variation of the test results remains within the acceptable range, go to Stage 3. If not, testing must continue to determine and eliminate the cause of variation. It might be necessary to return to Stage 1.

X2.3.3 Stage 3:

X2.3.3.1 Test three specimens in one unit monthly for as long as process stability has been established by achieving and maintaining acceptable variation of results. In case of unacceptable variation, testing must continue to determine and eliminate the cause of variation. It might be necessary to return to Stage 1 or Stage 2.

X2.3.3.2 It is possible to reduce the testing frequency further through the establishment of operating limits for the process control variables. For this to be accomplished, multi-level experimentation must be conducted to determine the impact of each variable on process performance.
ADDITONAL REFERENCES


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INTRODUCTION

This specification covers the coating of steel unified inch screw threaded fasteners by electrodeposition. The properties of the coatings shall conform to the ASTM standards for the individual finishes listed.

Coating thickness values are based on the tolerances for 1A and 2A external Unified Inch Screw Threads. The coating must not cause the basic thread size to be transgressed by either the internal or external threads. The method of designating coated threads shall comply with ASME B1.1.

With normal methods for depositing metallic coatings from aqueous solutions, there is a risk of delayed failure due to hydrogen embrittlement for case hardened fasteners and fasteners having a hardness 40 HRC or above. Although this risk can be managed by selecting raw materials suitable for the application of electrodeposited coatings and by using modern methods of surface treatment and post heat-treatment (baking), the risk of hydrogen embrittlement cannot be completely eliminated. Therefore, the application of a metallic coating by electrodeposition is not recommended for such fasteners.

1. Scope

1.1 This specification covers application, performance and dimensional requirements for electrodeposited coatings on threaded fasteners with unified inch screw threads. It specifies coating thickness, supplementary chromate finishes, corrosion resistance, precautions for managing the risk of hydrogen embrittlement and hydrogen embrittlement relief for high-strength and surface-hardened fasteners. It also highlights the differences between barrel and rack plating and makes recommendations as to the applicability of each process.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The following precautionary statement pertains to the test method portion only, Section 9, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
B 117 Practice for Operating Salt Spray (Fog) Apparatus
B 487 Test Method for Measurement of Metal and Oxide Coating Thickness by Microscopical Examination of a Cross Section
B 504 Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method
B 567 Test Method for Measurement of Coating Thickness by the Beta Backscatter Method
B 568 Test Method for Measurement of Coating Thickness by X-Ray Spectrometry
B 633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel
B 659 Guide for Measuring Thickness of Metallic and Inorganic Coatings
B 766 Specification for Electrodeposited Coatings of Cadmium
B 840 Specification for Electrodeposited Coatings of Zinc


2 Annual Book of ASTM Standards, Vol 03.02.
3 Annual Book of ASTM Standards, Vol 02.05.
3. Terminology

3.1 Definitions:

3.1.1 local thickness—the mean of the thickness measurements, of which a specified number is made within a reference area.

3.1.2 minimum local thickness—the lowest local thickness value on the significant surface of a single article.

3.1.3 reference area—the area within which a specified number of single measurements are required to be made.

3.1.4 significant surface—significant surfaces are areas where the minimum thickness to be met shall be designated on the applicable drawing or by the provision of a suitably marked sample. However, if not designated, significant surfaces shall be defined as those normally visible, directly or by reflection, which are essential to the appearance or serviceability of the fastener when assembled in normal position, or which can be the source of corrosion products that deface visible surfaces on the assembled fastener. Figs. 1 and 2 illustrate significant surfaces on standard externally threaded and internally threaded fasteners.

4. Classification

4.1 Coating Material—The coating material shall be selected and designated in accordance with Table 1.

4.2 Coating Thickness—The coating thickness shall be selected and designated in accordance with Table 2:

4.3 Chromate Finish—The chromate finish shall be selected and designated in accordance with Table 3.

5. Ordering Information for Electroplating

5.1 When ordering threaded fasteners to be coated by electrodeposition in accordance with this specification, the following information shall be supplied to the electroplater:

5.1.1 The desired coating, coating thickness and the chromate finish, or the classification codes as specified in Tables 1-3. (for example, Fe/Zn 5C denotes yellow zinc plated with a minimum thickness of 0.0002 in. on significant surfaces.)

5.1.2 The identification of significant surfaces (optional).

5.1.3 The requirement, if any, for stress relief before electroplating, in which case the stress-relief conditions must be specified.

5.1.4 The requirements, if any, for hydrogen embrittlement relief by heat treatment (baking) stating the tensile strength or surface hardness of the fasteners and/or baking time and temperature.

Note 1—Fasteners with a specified maximum hardness of 34 HRC and below have a very low susceptibility to hydrogen embrittlement and do not require baking.

5.1.5 The requirements, if any, for the type of electroplating process (barrel-plating or rack-plating). See Section 10 and Appendix X1.

5.1.6 The designation of coated thread class shall comply with ASME B1.1.
6. Requirements

6.1 Coating Requirements—The electrodeposited coating as ordered shall cover all surfaces and shall meet the following requirements:

6.1.1 The coating metal deposit shall be bright or semi-bright unless otherwise specified by the purchaser, smooth, fine grained, adherent and uniform in appearance.

6.1.2 The coating shall be free of blisters, pits, nodules, roughness, cracks, unplated areas, and other defects that will affect the function of the coating.

6.1.3 The coating shall not be stained, discolored or exhibit any evidence of white or red corrosion products.

6.1.3.1 Slight discoloration that results from baking, drying, or electrode contact during rack-plating, or all of these, as well as slight staining that results from rinsing shall not be cause for rejection.

6.2 Corrosion Resistance—Coated fasteners, when tested by continuous exposure to neutral salt spray in accordance with 9.3, shall show neither corrosion products of coatings (white corrosion) nor basis metal corrosion products (red rust) at the end of the test period. The appearance of corrosion products visible to the unaided eye at normal reading distance shall be cause for rejection, except when present at the edges of the tested fasteners. Refer to Annex A1 for neutral salt spray performance requirements for zinc, zinc alloy and cadmium coatings.

6.3 Thickness—The coating thickness shall comply with requirements of Table 2 when measured in accordance with 9.1.

6.3.1 Restrictions on Coating Thickness—This specification imposes minimum local thickness requirements at significant surfaces in accordance with Table 2. Thick or thin local thickness in a location other than a significant surface shall not be a cause for rejection. However the following restrictions apply:

6.3.1.1 Minimum coating thickness at low current density areas, such as the center of a bolt or recesses, must be sufficient to provide for adequate chromate adhesion.

6.3.1.2 External Threads—Maximum coating thickness at high current density threaded tips must provide for class 3A GO thread gage acceptance.

6.3.1.3 Internal Threads—Maximum coating thickness of internal threads must provide for class 1B, 2B, or 3B GO thread gage acceptance.

6.3.1.4 Surfaces such as threads, holes, deep recesses, bases of angles, and similar areas on which the specified thickness of deposit cannot readily be controlled, are exempted from minimum thickness requirements unless they are specially designated as not being exempted. When such areas are subject to minimum thickness requirements, the purchaser and the manufacturer shall recognize the necessity for either thinner deposits on other areas or special racking.

6.3.2 Applicability to Unified Inch Screw Threads:

6.3.2.1 The applicability of the required coating to unified inch screw threads is limited by the basic deviation of the threads, and hence limited by the pitch diameter, allowance and tolerance positions. Refer to Appendix X3 as a guideline for the tolerances of the various thread sizes and classes and the coating thickness they will accommodate.

6.3.2.2 Because of the inherent variability in coating thickness by the barrel-plating process, the application of a minimum coating thickness of 0.0005 in. is not recommended for a standard screw thread by this method due to the fact that dimensional allowance of most threaded fasteners normally does not permit it. If the size of the fastener is large enough to economically use the rack-plating process, then the latter shall be used to obtain this thickness requirement. If heavier coatings are required allowance for the deposit buildup must be made during the manufacture of fasteners.

6.3.3 Applicability to Wood Screws and Thread Forming Screws—Any classification code in Table 2 may be applied to screws that cut or form their own threads.

6.4 Hydrogen Embrittlement Relief:

6.4.1 Requirement for Baking—Coated fasteners made from steel heat treated to a specified hardness of 40 HRC or above, case-hardened steel fasteners, and fasteners with captive washers made from hardened steel shall be baked to minimize the risk of hydrogen embrittlement. Unless otherwise specified by the purchaser, baking is not mandatory for fasteners with specified maximum hardness below 40 HRC.

NOTE 2—With proper care many steel fasteners can be plated without baking by correlating process conditions to the susceptibility of the fastener material to hydrogen embrittlement, and by applying adequate process control procedures, such as those outlined in Appendix X4.2. Test Method F 1940 is a recognized verification method for process control to minimize the risk of hydrogen embrittlement. Upon agreement between the supplier and the purchaser, this test method can be used as a basis for
6.4.2 Baking Conditions—At the time of publication of this specification it was not considered possible to give an exact baking duration. Eight hours is considered a typical example of baking duration. However, upon agreement between the purchaser and the manufacturer, baking times between 2 and 24 h at temperatures of 350 to 450°F are suitable depending on the type and size of the fastener, geometry, mechanical properties, cleaning process and cathodic efficiency of the electroplating process used. The baking conditions shall be selected based on the results of recognized embrittlement test procedures such as Test Methods F 606, F 1624, F 1940, or NASM–1312–5.

6.4.2.1 Bake time and temperatures may require lowering to minimize the risk of solid or liquid metal embrittlement resulting from alloy compositions such as those containing lead or from the lower melting point of cadmium (610°F) in comparison to zinc (786°F).

6.4.2.2 Fasteners must be baked within 4 h, preferably 1 h after electroplating. Baking to relieve hydrogen embrittlement must be performed prior to the application of the chromate finish because temperatures above 150°F damage the chromate film thereby negating its performance.

6.4.3 Hydrogen Embrittlement Testing—Hydrogen embrittlement testing is mandatory for fasteners with a specified hardness of 40 HRC or above unless the electroplating process has been qualified in accordance with Test Method F 1940 (that is, the process has been shown not to cause embrittlement for a given product or class of product). This specification does not require mandatory testing of fasteners having a specified hardness below 40 HRC, unless otherwise specified by the purchaser.

7. Dimensional Requirements

7.1 Threaded components, except those with spaced and forming threads, supplied for electrodeposited coating shall comply with ASME B1.1. Screw threads that are specifically manufactured to allow the application of 0.0005 in. or greater coating thickness by the barrel-plating process, must adhere to a special allowance specified by the manufacturer or in ASME B1.1. The other dimensional characteristics shall be as specified in the applicable standard or drawing. It should be noted that modifications to the threads of a fastener could affect its properties or performance, or both. Refer to Appendix X3 for further information on effects of coating on pitch diameter, allowances and tolerances for external and internal threads.

8. Sampling

8.1 Sampling for coating thickness, salt spray and embrittlement testing shall be conducted based on lot size in accordance with Guide F 1470.

9. Test Methods

9.1 Coating Thickness—Unless otherwise specified, the requirement to measure coating thickness is applicable to significant surfaces only. The test methods for determining the coating thickness are defined in Test Methods B 487, B 499, B 504, B 567, B 568, Guide B 659, or Practice E 376 as applicable.

9.2 Embrittlement Test Method—The embrittlement test method shall conform to those specified in Test Methods F 1940 for process verification, or F 606, F 1624, or NASM–1312–5 for product testing.

9.3 Corrosion Resistance—The requirement to determine corrosion resistance is applicable to significant surfaces only. When specified in the contract or purchase order, a salt spray test shall be conducted in accordance with Practice B 117. To secure uniformity of results, samples shall be aged at room temperature for 24 h before being subjected to the salt spray test.

10. Electroplating Processes

10.1 Two electroplating processes are most commonly used to apply a metallic coating by electrodeposition on threaded fasteners: barrel-plating and rack-plating. When thread fit or thread integrity, or both, is a concern for externally threaded fasteners, rack-plating is preferable to barrel-plating. Refer to Appendix X1.
### A1. NEUTRAL SALT SPRAY PERFORMANCE

#### TABLE A1.1 Classification Code and Neutral Salt Spray Corrosion Protection Performance of Zinc and Cadmium Coatings

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<tr>
<td>Fe/Zn or Fe/Cd 3B</td>
<td>. . .</td>
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<tr>
<td>Fe/Zn or Fe/Cd 5A</td>
<td>0.0002</td>
<td>A</td>
<td>6</td>
<td>48</td>
<td>24</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 5B</td>
<td>. . .</td>
<td>B</td>
<td>12</td>
<td>72</td>
<td>36</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 5C</td>
<td>. . .</td>
<td>C</td>
<td>48</td>
<td>120</td>
<td>72</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 5D</td>
<td>. . .</td>
<td>D</td>
<td>72</td>
<td>168</td>
<td>96</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 5E</td>
<td>. . .</td>
<td>E</td>
<td>12</td>
<td>72</td>
<td>. . .</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 8A</td>
<td>0.0003</td>
<td>A</td>
<td>6</td>
<td>96</td>
<td>48</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 8B</td>
<td>. . .</td>
<td>B</td>
<td>24</td>
<td>120</td>
<td>72</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 8C</td>
<td>. . .</td>
<td>C</td>
<td>72</td>
<td>168</td>
<td>120</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 8D</td>
<td>. . .</td>
<td>D</td>
<td>96</td>
<td>192</td>
<td>144</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 8E</td>
<td>. . .</td>
<td>E</td>
<td>24</td>
<td>120</td>
<td>72</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 12A</td>
<td>0.0005</td>
<td>A</td>
<td>6</td>
<td>144</td>
<td>72</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 12B</td>
<td>. . .</td>
<td>B</td>
<td>24</td>
<td>192</td>
<td>96</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 12C</td>
<td>. . .</td>
<td>C</td>
<td>72</td>
<td>240</td>
<td>144</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 12D</td>
<td>. . .</td>
<td>D</td>
<td>96</td>
<td>264</td>
<td>168</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 12F</td>
<td>. . .</td>
<td>E</td>
<td>24</td>
<td>192</td>
<td>96</td>
</tr>
</tbody>
</table>

<sup>4</sup> Low coating thickness impairs chromate adhesion and performance.

#### TABLE A1.2 Classification Code and Neutral Salt Spray Corrosion Protection Performance of Zinc-Cobalt Coatings

<table>
<thead>
<tr>
<th>Classification Code</th>
<th>Minimum Coating Thickness, in.</th>
<th>Chromate Finish Designation</th>
<th>First Appearance of Zinc Alloy Corrosion Product, (hour)</th>
<th>First Appearance of Red Rust (hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe/Zn-Co 5C</td>
<td>0.0002</td>
<td>C</td>
<td>96</td>
<td>240</td>
</tr>
<tr>
<td>Fe/Zn-Co 5D</td>
<td>. . .</td>
<td>D</td>
<td>96</td>
<td>240</td>
</tr>
<tr>
<td>Fe/Zn-Co 5E</td>
<td>. . .</td>
<td>E</td>
<td>100</td>
<td>240</td>
</tr>
<tr>
<td>Fe/Zn-Co 5F</td>
<td>. . .</td>
<td>F</td>
<td>196</td>
<td>340</td>
</tr>
<tr>
<td>Fe/Zn-Co 8C</td>
<td>0.0003</td>
<td>C</td>
<td>96</td>
<td>240</td>
</tr>
<tr>
<td>Fe/Zn-Co 8D</td>
<td>. . .</td>
<td>D</td>
<td>96</td>
<td>240</td>
</tr>
<tr>
<td>Fe/Zn-Co 8E</td>
<td>. . .</td>
<td>E</td>
<td>100</td>
<td>240</td>
</tr>
<tr>
<td>Fe/Zn-Co 8F</td>
<td>. . .</td>
<td>F</td>
<td>200</td>
<td>340</td>
</tr>
<tr>
<td>Fe/Zn-Co 12B</td>
<td>0.0005</td>
<td>B</td>
<td>12</td>
<td>240</td>
</tr>
<tr>
<td>Fe/Zn-Co 12C</td>
<td>. . .</td>
<td>C</td>
<td>96</td>
<td>400</td>
</tr>
<tr>
<td>Fe/Zn-Co 12D</td>
<td>. . .</td>
<td>D</td>
<td>96</td>
<td>400</td>
</tr>
<tr>
<td>Fe/Zn-Co 12E</td>
<td>. . .</td>
<td>E</td>
<td>100</td>
<td>400</td>
</tr>
<tr>
<td>Fe/Zn-Co 12F</td>
<td>. . .</td>
<td>F</td>
<td>196</td>
<td>500</td>
</tr>
</tbody>
</table>
X1.1 Barrel-Plating Process—The preparation and metallic coating of threaded fasteners is usually accomplished by the barrel-plating process. In this process, quantities of an item are placed within a containment vessel, called a barrel. The barrel is designed to move the group of items, together, through each of the process steps, allowing ready ingress and egress of processing solutions and rinses. As the barrel is moved through the process steps, it is also rotated such that the individual items are constantly cascading over one another. This can damage the external threads of fasteners. The effect of thread damage is worse on heavy fine threaded fasteners than on light course threaded fasteners. In some of the process steps, notably the electrocleaning and electroplating steps, an electric current is applied to the group of items. The cascading action randomly exposes the surface of each individual piece to the process electrodes while also maintaining electrical continuity between all of the parts. The local coating thickness on a part is a result of the electrical current density at that location. Therefore, the
coating thickness on an individual screw or bolt tends to be greatest at the extremities (head and threaded tip). The extremities being the high current density areas receive the greatest coating thickness. In contrast, the center or recesses such as the bottom of the threads, which are the low current density areas, receive the lowest coating thickness. This phenomenon is accentuated with increasing length and decreasing diameter of the screw or bolt. The extremity-to-center coating thickness ratio increases with increasing length and decreasing diameter, but is also a function of process parameters such as plating solution chemistry and efficiency, anodic/cathodic efficiency, average current density and plating time.

X1.2 Rack-Plating Process—The preparation and metallic coating of threaded fasteners can be accomplished by the rack-plating process, particularly on large size fasteners where thread fit and/or damage is a concern, or for smaller size fasteners, when it is economically feasible. In this process, quantities of an item are placed on a support, called a rack. The rack is designed to move the group of items, together, through each of the process steps, allowing ready ingress and egress of processing solutions and rinses. In some of the process steps, notably the electrocleaning and electroplating steps, an electric current is applied to the group of items. The electrical continuity is maintained between the parts by the rack itself. The average current density is usually low enough such that the extremity-to-center coating thickness ratio is much lower than with barrel-plating. The external thread damage is also minimized in comparison to barrel-plating due to the absence of tumbling.

X2. GUIDELINES FOR CHOOSING BETWEEN BARREL-PLATING AND RACK-PLATING

X2.1 Short screws and bolts are those with a length-to-diameter ratio equal to or less than 5. Long screws and bolts have a length-to-diameter ratio greater than 5 but less than 10. Special processing is normally required for bolts with a ratio greater than 10 in order to minimize the extremity-to-center thickness ratio.

X2.2 Tables X2.1 and X2.2 indicate the recommended electroplating process for each size of externally coarse (UNC) and fine (UNF) threaded fasteners for all thickness classes in Table 2. For externally thread fasteners with UNS and UN thread series, rack-plating is recommended. For internally threaded fasteners barrel-plating is generally suitable.

### TABLE X2.1 Recommended Electroplating Process for Each Size of Externally Coarse Threaded Fasteners (UNC)

<table>
<thead>
<tr>
<th>Diameter (D), (in.)</th>
<th>Length (L)</th>
<th>L ≤ 5D</th>
<th>5D &lt; L ≤ 10D</th>
<th>10D &lt; L ≤ 20D</th>
<th>20D &lt; L ≤ 30D</th>
<th>L &gt; 30D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1⁄4</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>R</td>
</tr>
<tr>
<td>5⁄32</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>R</td>
</tr>
<tr>
<td>3⁄16</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>R</td>
</tr>
<tr>
<td>7⁄32</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>1⁄2</td>
<td>B</td>
<td>B</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>9⁄32</td>
<td>B</td>
<td>B</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>5⁄16</td>
<td>B</td>
<td>B</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>3⁄8</td>
<td>B</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>7⁄8</td>
<td>B</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>1 – 4</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
</tbody>
</table>
X3. COATING ACCOMMODATION TOLERANCES FOR EXTERNALLY AND INTERNALLY THREADED FASTENERS

X3.1 This specification does not impose maximum thickness values on high current density areas, where the coating thickness tends to be the greatest. On an externally threaded fastener this occurs at the threaded tip. Measuring coating thickness on the threaded portion of a fastener is possible but impractical for in-process quality control verification. For this reason the control mechanism specified in this document is by means of GO thread gauges. Nevertheless Tables X3.1-X3.4 illustrate maximum coating thickness permitted by Class 1A and 2A allowance, and are supplied as an informative guideline.

Note X3.1—The following information is based on ASME B1.1 Section 7. That standard should be consulted for more detailed information.

X3.2 Size limits for standard external 1A and 2A thread classes apply prior to coating. The external thread allowance may thus be used to accommodate the coating thickness on threaded fasteners, provided the maximum coating thickness is no more than \( \frac{1}{4} \) of the allowance. Thus, threads after coating are subject to acceptance using a basic Class 3A GO gage and a class 2A gage as a NOT-GO gage.

X3.3 In certain cases size limits must be adjusted, within the tolerances, prior to coating, in order to insure proper thread fit. This applies to the following cases:

X3.3.1 Standard internal threads, because they provide no allowance for coating thickness.

X3.3.2 Where the external thread has no allowance, such as Class 3A threads.

TABLE X3.1 Coating Accommodation Tolerances for Externally Coarse Threaded (UNC) Fasteners

<table>
<thead>
<tr>
<th>Thread Pitch, TPI</th>
<th>Diameter, in.</th>
<th>Pitch Diameter Allowance for 1A and 2A Thread Classes, in.</th>
<th>Maximum Allowable Coating Thickness on Threaded Tip, ( \times \frac{0.0001}{\text{in.}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>( \frac{1}{4} )</td>
<td>0.0011</td>
<td>2.75</td>
</tr>
<tr>
<td>18</td>
<td>( \frac{5}{16} )</td>
<td>0.0012</td>
<td>3.00</td>
</tr>
<tr>
<td>16</td>
<td>( \frac{3}{8} )</td>
<td>0.0013</td>
<td>3.25</td>
</tr>
<tr>
<td>14</td>
<td>( \frac{7}{16} )</td>
<td>0.0014</td>
<td>3.50</td>
</tr>
<tr>
<td>13</td>
<td>( \frac{1}{2} )</td>
<td>0.0015</td>
<td>3.75</td>
</tr>
<tr>
<td>12</td>
<td>( \frac{9}{16} )</td>
<td>0.0016</td>
<td>4.00</td>
</tr>
<tr>
<td>11</td>
<td>( \frac{5}{8} )</td>
<td>0.0018</td>
<td>4.50</td>
</tr>
<tr>
<td>10</td>
<td>( \frac{3}{4} )</td>
<td>0.0019</td>
<td>4.75</td>
</tr>
<tr>
<td>9</td>
<td>( \frac{7}{8} )</td>
<td>0.0020</td>
<td>5.00</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>0.0022</td>
<td>5.50</td>
</tr>
<tr>
<td>7</td>
<td>1 ( \frac{1}{4} ) and 1 ( \frac{1}{2} )</td>
<td>0.0024</td>
<td>6.00</td>
</tr>
<tr>
<td>6</td>
<td>1 ( \frac{3}{4} ) and 1 ( \frac{1}{2} )</td>
<td>0.0027</td>
<td>6.75</td>
</tr>
<tr>
<td>5</td>
<td>1 ( \frac{1}{2} )</td>
<td>0.0027</td>
<td>7.25</td>
</tr>
<tr>
<td>4 ( \frac{1}{8} )</td>
<td>2 and 2 ( \frac{1}{4} )</td>
<td>0.0029</td>
<td>7.75</td>
</tr>
<tr>
<td>4</td>
<td>2 ( \frac{1}{4} )</td>
<td>0.0031</td>
<td>7.75</td>
</tr>
<tr>
<td>4</td>
<td>2 ( \frac{3}{8} ) and 3</td>
<td>0.0032</td>
<td>8.00</td>
</tr>
<tr>
<td>4</td>
<td>3 ( \frac{1}{4} ) and 3 ( \frac{1}{2} )</td>
<td>0.0033</td>
<td>8.25</td>
</tr>
<tr>
<td>4</td>
<td>3 ( \frac{3}{4} ) and 4</td>
<td>0.0034</td>
<td>8.50</td>
</tr>
</tbody>
</table>

X3.3.3 Where allowance must be maintained after coating for trouble free thread fit.

X3.4 Tables X3.1-X3.4 provide maximum thickness values based only on the allowance for the 1A and 2A thread classes. It assumes that the external thread pitch diameter is at the maximum and that the internal thread pitch diameter is at the minimum of the tolerance (see Fig. X3.1).
### TABLE X3.2 Coating Accommodation Tolerances for Externally Fine Threaded (UNF) Fasteners

<table>
<thead>
<tr>
<th>Thread Pitch, TPI</th>
<th>Diameter, in.</th>
<th>Pitch Diameter Allowance for 1A and 2A Thread Classes, in.</th>
<th>Maximum Allowable Coating Thickness on Threaded Tip, $\times 0.0001$ in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>$\frac{1}{8}$</td>
<td>0.0010</td>
<td>2.50</td>
</tr>
<tr>
<td>24</td>
<td>$\frac{3}{8}$ and $\frac{1}{4}$</td>
<td>0.0011</td>
<td>2.75</td>
</tr>
<tr>
<td>20</td>
<td>$\frac{5}{16}$ and $\frac{1}{8}$</td>
<td>0.0013</td>
<td>3.25</td>
</tr>
<tr>
<td>18</td>
<td>$\frac{7}{32}$ and $\frac{3}{16}$</td>
<td>0.0014</td>
<td>3.50</td>
</tr>
<tr>
<td>16</td>
<td>$\frac{9}{64}$</td>
<td>0.0015</td>
<td>3.75</td>
</tr>
<tr>
<td>14</td>
<td>$\frac{1}{4}$</td>
<td>0.0016</td>
<td>4.00</td>
</tr>
<tr>
<td>12</td>
<td>1, 1 $\frac{1}{8}$ and 1 $\frac{1}{4}$</td>
<td>0.0018</td>
<td>4.50</td>
</tr>
<tr>
<td>12</td>
<td>1 $\frac{1}{4}$ and 1 $\frac{1}{2}$</td>
<td>0.0019</td>
<td>4.75</td>
</tr>
</tbody>
</table>

### TABLE X3.3 Coating Accommodation Tolerances for Externally Threaded (UNS) Fasteners

<table>
<thead>
<tr>
<th>Thread Pitch, TPI</th>
<th>Diameter, in.</th>
<th>Pitch Diameter Allowance for 1A and 2A Thread Classes, in.</th>
<th>Maximum Allowable Coating Thickness on Threaded Tip, $\times 0.0001$ in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>1</td>
<td>0.0017</td>
<td>4.25</td>
</tr>
</tbody>
</table>

### TABLE X3.4 Coating Accommodation Tolerances for Externally Threaded (UN) Fasteners

<table>
<thead>
<tr>
<th>Thread Pitch, TPI</th>
<th>Diameter, in.</th>
<th>Pitch Diameter Allowance for 1A and 2A Thread Classes, in.</th>
<th>Maximum Allowable Coating Thickness on Threaded Tip, $\times 0.0001$ in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>1 $\frac{1}{8}$ and 1 $\frac{1}{4}$</td>
<td>0.0021</td>
<td>5.25</td>
</tr>
<tr>
<td>8</td>
<td>1 $\frac{3}{16}$, 1 $\frac{1}{2}$ and 1 $\frac{7}{16}$</td>
<td>0.0022</td>
<td>5.50</td>
</tr>
<tr>
<td>8</td>
<td>1 $\frac{3}{8}$, 1 $\frac{1}{8}$ and 2</td>
<td>0.0023</td>
<td>5.75</td>
</tr>
<tr>
<td>8</td>
<td>2 $\frac{1}{4}$ and 2 $\frac{1}{2}$</td>
<td>0.0024</td>
<td>6.00</td>
</tr>
<tr>
<td>8</td>
<td>2 $\frac{3}{4}$</td>
<td>0.0025</td>
<td>6.25</td>
</tr>
<tr>
<td>8</td>
<td>3, 3 $\frac{1}{4}$ and 3 $\frac{1}{2}$</td>
<td>0.0026</td>
<td>6.50</td>
</tr>
<tr>
<td>8</td>
<td>3 $\frac{3}{8}$ and 4</td>
<td>0.0027</td>
<td>6.75</td>
</tr>
</tbody>
</table>

---

**FIG. X3.1** Relationship of Pitch Diameter Allowance for Classes of Fit on $\frac{1}{8}$-13 UNC Thread
X4. APPLICATION REQUIREMENTS

X4.1 Cleaning of Basis Metal—Thorough cleaning of the basis metal is essential in order to ensure satisfactory adhesion, appearance and corrosion resistance of the coating.

X4.2 Hydrogen Embrittlement Risk Management:

X4.2.1 Process Considerations—The following are some general recommendations for managing the risk of hydrogen embrittlement. For more detailed information refer to IFI-142 “Hydrogen Embrittlement Risk Management”.

X4.2.1.1 Clean the fasteners in non-cathodic alkaline solutions and in inhibited acid solutions.

X4.2.1.2 Use abrasive cleaners for fasteners having a hardness of 40 HRC or above and case hardened fasteners.

X4.2.1.3 Manage anode/cathode surface area and efficiency, resulting in proper control of applied current densities. High current densities increase hydrogen charging.

X4.2.1.4 Use high efficiency plating processes such as zinc chloride or acid cadmium.

X4.2.1.5 Control the plating bath temperature to minimize the use of brighteners.

X4.2.1.6 Select raw materials with a low susceptibility to hydrogen embrittlement by controlling steel chemistry, microstructure, and mechanical properties.

X4.2.2 Process Control Verification—Test Method F 1940 should be used as a test method for process control to minimize the risk of hydrogen embrittlement. Periodic inspections should be conducted according to a specified test plan. The test plan should be designed based upon the specific characteristics of a process, and upon agreement between the purchaser and the manufacturer. The testing frequency should initially establish and subsequently verify over time, the ability of a process to produce parts that do not have the potential for hydrogen embrittlement.

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INTRODUCTION

This specification covers the coating of steel metric screw threaded fasteners by electrodeposition. The properties of the coatings shall conform to the ASTM standards for the individual finishes listed. Coating thickness values are based on the tolerances for \( M \) series metric threads having the following tolerance positions: 6g and 4g6g for external threads, and 6H for internal threads. The coating must not cause the basic thread size to be transgressed by either the internal or external threads. The method of designating coated threads shall comply with ASME B1.13M.

With normal methods for depositing metallic coatings from aqueous solutions, there is a risk of delayed failure due to hydrogen embrittlement for case hardened fasteners and fasteners having a hardness 40 HRC or above. Although this risk can be managed by selecting raw materials suitable for the application of electrodeposited coatings and by using modern methods of surface treatment and post heat-treatment (baking), the risk of hydrogen embrittlement cannot be completely eliminated. Therefore, the application of a metallic coating by electrodeposition is not recommended for such fasteners.

1. Scope

1.1 This specification covers application, performance and dimensional requirements for electrodeposited coatings on threaded fasteners with metric screw threads. It specifies coating thickness, supplementary chromate finishes, corrosion resistance, precautions for managing the risk of hydrogen embrittlement and hydrogen embrittlement relief for high-strength and surface-hardened fasteners. It also highlights the differences between barrel and rack plating and makes recommendations as to the applicability of each process.

1.2 The following precautionary statement pertains to the test method portion only, Section 9, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
B 117 Practice for Operating Salt Spray (Fog) Apparatus
B 487 Test Method for Measurement of Metal and Oxide Coating Thickness by Microscopical Examination of a Cross Section
B 504 Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method
B 567 Test Method for Measurement of Coating Thickness by the Beta Backscatter Method
B 568 Test Method for Measurement of Coating Thickness by X-Ray Spectrometry
B 633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel
B 659 Guide for Measuring Thickness of Metallic and Inorganic Coatings

1 This specification is under the jurisdiction of ASTM Committee F-16 on Fasteners and is the direct responsibility of Subcommittee F16.03 on Coatings on Fasteners.

2 Annual Book of ASTM Standards, Vol 03.02.
3 Annual Book of ASTM Standards, Vol 02.05.
3. Terminology

3.1 Definitions:

3.1.1 local thickness—the mean of the thickness measurements, of which a specified number is made within a reference area.

3.1.2 minimum local thickness—the lowest local thickness value on the significant surface of a single article.

3.1.3 reference area—the area within which a specified number of single measurements are required to be made.

3.1.4 significant surface—significant surfaces are areas where the minimum thickness to be met shall be designated on the applicable drawing or by the provision of a suitably marked sample. However, if not designated, significant surfaces shall be defined as those normally visible, directly or by reflection, which are essential to the appearance or serviceability of the fastener when assembled in normal position, or which can be the source of corrosion products that deface visible surfaces on the assembled fastener. Figs. 1 and 2 illustrate significant surfaces on standard externally threaded and internally threaded fasteners.

4. Classification

4.1 Coating Material—The coating material shall be selected and designated in accordance with Table 1.

4.2 Coating Thickness—The coating thickness shall be selected and designated in accordance with Table 2.

4.3 Chromate Finish—The chromate finish shall be selected and designated in accordance with Table 3.

5. Ordering Information for Electroplating

5.1 When ordering threaded fasteners to be coated by electrodeposition in accordance with this specification, the following information shall be supplied to the electroplater:

5.1.1 The desired coating, coating thickness and the chromate finish, or the classification codes as specified in Tables 1-3. (For example, Fe/Zn 5C denotes yellow zinc plated with a minimum thickness of 5 µm on significant surfaces.)

5.1.2 The identification of significant surfaces (optional).

5.1.3 The requirement, if any, for stress relief before electroplating, in which case the stress-relief conditions must be specified.

5.1.4 The requirements, if any, for hydrogen embrittlement relief by heat treatment (baking) stating the tensile strength or surface hardness of the fasteners and/or baking time and temperature.

5.1.5 The requirements, if any, for the type of electroplating process (barrel-plating or rack-plating). See Section 10 and Appendix X1.

5.1.6 The designation of coated thread class shall comply with ASME B1.13M.
6. Requirements

6.1 Coating Requirements—The electrodeposited coating as ordered shall cover all surfaces and shall meet the following requirements:

6.1.1 The coating metal deposit shall be bright or semibright unless otherwise specified by the purchaser, smooth, fine grained, adherent and uniform in appearance.

6.1.2 The coating shall be free of blisters, pits, nodules, roughness, cracks, unplated areas, and other defects that will affect the function of the coating.

6.1.3 The coating shall not be stained, discolored or exhibit any evidence of white or red corrosion products.

6.1.3.1 Slight discoloration that results from baking, drying, or electrode contact during rack-plating, or all of these, as well as slight staining that results from rinsing shall not be a cause for rejection.

6.2 Corrosion Resistance—Coated fasteners, when tested by continuous exposure to neutral salt spray in accordance with 9.3, shall show neither corrosion products of coatings (white corrosion) nor basis metal corrosion products (red rust) at the end of the test period. The appearance of corrosion products visible to the unaided eye at normal reading distance shall be cause for rejection, except when present at the edges of the tested fasteners. Refer to Annex A1 for neutral salt spray performance requirements for zinc, zinc alloy and cadmium coatings.

6.3 Thickness—The coating thickness shall comply with requirements of Table 2 when measured in accordance with 9.1.

6.3.1 Restrictions on Coating Thickness—This specification imposes minimum local thickness requirements at significant surfaces in accordance with Table 2. Thick or thin local thickness in a location other than a significant surface shall not be a cause for rejection. However the following restrictions apply:

6.3.1.1 Minimum coating thickness at low current density areas, such as the center of a bolt or recesses, must be sufficient to provide for adequate chromate adhesion.

6.3.1.2 External Threads—Maximum coating thickness at high current density threaded tips must provide for basic (tolerance position h) GO thread gauge acceptance. Therefore, the thread after coating is subject to acceptance using a class 6h GO gauge for plated 6g class external threads and 4h6h GO gauge for plated 4g6g class external threads respectively.

6.3.1.3 Internal Threads—Maximum coating thickness of internal threads must provide for basic (tolerance position H) GO thread gauge acceptance. Therefore, the thread after coating is subject to acceptance using a class 6H GO gauge for 6H class internal threads.

6.3.1.4 Surfaces such as threads, holes, deep recesses, bases of angles, and similar areas on which the specified thickness of deposit cannot readily be controlled, are exempted from minimum thickness requirements unless they are specially designated as not being exempted. When such areas are subject to minimum thickness requirements, the purchaser and the manufacturer shall recognize the necessity for either thicker deposits on other areas or special racking.

6.3.2 Applicability to M Series Threads:

6.3.2.1 The applicability of the required coating to M series metric threads is limited by the basic deviation of the threads, and hence limited by the pitch diameter, allowance, and tolerance positions. Refer to Appendix X3 as a guideline for the tolerances of the various thread sizes and classes and the coating thickness they will accommodate.

6.3.2.2 Because of the inherent variability in coating thickness by the barrel-plating process, the application of a minimum coating thickness of 12 µm is not recommended for a standard screw thread by this method due to the fact that dimensional allowance of many metric threaded fasteners normally does not permit it. If the size of the fastener is large enough to economically use the rack-plating process, then the latter shall be used to obtain this thickness requirement. If heavier coatings are required, allowance for the deposit buildup must be made during the manufacture of fasteners.

6.3.3 Applicability to Wood Screws and Thread Forming Screws—Any classification code in Table 2 may be applied to screws that cut or form their own threads.

6.4 Hydrogen Embrittlement Relief:

6.4.1 Requirement for Baking—Coated fasteners made from steel heat treated to a specified hardness of 40 HRC or above, case-hardened steel fasteners, and fasteners with captive washers made from hardened steel, shall be baked to minimize the risk of hydrogen embrittlement. Unless otherwise specified by the purchaser, baking is not mandatory for fasteners with specified maximum hardness below 40 HRC.

**TABLE 1 Designation of Common Coating Materials**

<table>
<thead>
<tr>
<th>Coating Designation</th>
<th>Coating Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe/Zn</td>
<td>Zinc</td>
</tr>
<tr>
<td>Fe/Cd</td>
<td>Cadmium</td>
</tr>
<tr>
<td>Fe/Zn-Co</td>
<td>Zinc Cobalt Alloy</td>
</tr>
<tr>
<td>Fe/Zn-Ni</td>
<td>Zinc Nickel Alloy</td>
</tr>
<tr>
<td>Fe/Zn-Fe</td>
<td>Zinc Iron Alloy</td>
</tr>
</tbody>
</table>

**TABLE 2 Designation of Coating Thickness**

<table>
<thead>
<tr>
<th>Thickness Designation</th>
<th>Minimum Thickness µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
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<tr>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

**TABLE 3 Designation of Chromate Finish**

<table>
<thead>
<tr>
<th>Designation</th>
<th>Type</th>
<th>Typical Appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Clear</td>
<td>Transparent colorless with slight iridescence</td>
</tr>
<tr>
<td>B</td>
<td>Blue-bright</td>
<td>Transparent with a bluish tinge and slight iridescence</td>
</tr>
<tr>
<td>C</td>
<td>Yellow</td>
<td>Yellow iridescent</td>
</tr>
<tr>
<td>D</td>
<td>Opaque</td>
<td>Olive green, shading to brown or bronze</td>
</tr>
<tr>
<td>E</td>
<td>Black</td>
<td>Black with slight iridescence</td>
</tr>
<tr>
<td>F</td>
<td>Organic</td>
<td>Any of the above plus organic topcoat</td>
</tr>
</tbody>
</table>

Note 1—The conversion factor from microns to inch is 3.94 × 10^{-5} (for example, 5 µm = 0.00002 in.).
F 1940 is a recognized verification method for process control to minimize the risk of hydrogen embrittlement. Upon agreement between the supplier and the purchaser, this test method can be used as a basis for determining if baking should be mandated in a controlled process environment.

6.4.2 **Baking Conditions**—At the time of publication of this specification it was not considered possible to give an exact baking duration. Eight hours is considered a typical example of baking duration. However, upon agreement between the purchaser and the manufacturer, baking times between 2 and 24 h at temperatures of 175 to 235°C (350 to 450°F) are suitable depending on the type and size of the fastener, geometry, mechanical properties, cleaning process and cathodic efficiency of the electroplating process used. The baking conditions shall be selected based on the results of recognized embrittlement test procedures such as Test Methods F 1940, F 1624, F 606, or NASM 1312-5.

6.4.2.1 Bake time and temperatures may require lowering to minimize the risk of solid or liquid metal embrittlement resulting from alloy compositions such as those containing lead or from the lower melting point of cadmium 320°C (610°F) in comparison to zinc 419°C (786°F).

6.4.2.2 Fasteners must be baked within 4 h, preferably 1 h after electroplating. Baking to relieve hydrogen embrittlement must be performed prior to the application of the chromate finish because temperatures above 65°C (150°F) damage the chromate film thereby negating its performance.

6.4.3 **Hydrogen Embrittlement Testing**—Hydrogen embrittlement testing is mandatory for fasteners with a specified hardness of 40 HRC or above, unless the electroplating process has been qualified in accordance with Test Method F 1940 (that is, the process has been shown not to cause embrittlement for a given product or class of product). This specification does not require mandatory testing of fasteners having a specified hardness below 40 HRC, unless otherwise specified by the purchaser.

7. **Dimensional Requirements**

7.1 Threaded components, except those with spaced and forming threads, supplied for electrodeposited coating shall comply with ASME B1.13M. Screw threads that are specifically manufactured to allow the application of 12 µm or greater coating thickness by the barrel-plating process, must adhere to a special allowance specified by the manufacturer or in ASME B1.13M. The other dimensional characteristics shall be as specified on the applicable standard or drawing. It should be noted that modifications to the threads of a fastener could affect its properties or performance, or both. Refer to Appendix X3 for further information on effects of coating on pitch diameter, allowances and tolerances for external and internal threads.

8. **Sampling**

8.1 Sampling for coating thickness, salt spray and embrittlement testing shall be conducted based on lot size in accordance with Guide F 1470.

9. **Test Methods**

9.1 **Coating Thickness**—Unless otherwise specified, the requirement to measure coating thickness is applicable to significant surfaces only. The test methods for determining the coating thickness are defined in Test Methods B 487, B 499, B 504, B 567, B 568, Guide B 659 or Practice E 376 as applicable.

9.2 **Embrittlement Test Method**—The embrittlement test method shall conform to those specified in Test Method F 1940 for process verification, or Test Methods F 606, F 1624, or NASM-1312-5 for product testing.

9.3 **Corrosion Resistance**—The requirement to determine corrosion resistance is applicable to significant surfaces only. When specified in the contract or purchase order, salt spray testing shall be conducted in accordance with Practice B 117. To secure uniformity of results, samples shall be aged at room temperature for 24 h before being subjected to the salt spray test.

10. **Electroplating Processes**

10.1 Two electroplating processes are most commonly used to apply a metallic coating by electrodeposition on threaded fasteners: barrel-plating and rack-plating. When thread fit or thread integrity, or both, is a concern for externally threaded fasteners, rack-plating is preferable to barrel-plating. Refer to Appendix X1.
## ANNEX

(Mandatory Information)

### A1. NEUTRAL SALT SPRAY PERFORMANCE

#### TABLE A1.1 Classification Code and Neutral Salt Spray Corrosion Protection Performance of Zinc and Cadmium Coatings

<table>
<thead>
<tr>
<th>Classification Code</th>
<th>Minimum Coating Thickness (µm)</th>
<th>Chromate Finish Designation</th>
<th>First Appearance of White Corrosion Product, (hour)</th>
<th>First Appearance of Red Rust Cadmium, (hour)</th>
<th>First Appearance of Red Rust Zinc, (hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe/Zn or Fe/Cd 3A</td>
<td>3(^a)</td>
<td>A</td>
<td>3</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 3B</td>
<td>B</td>
<td>6</td>
<td></td>
<td>24</td>
<td></td>
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<tr>
<td>Fe/Zn or Fe/Cd 3C</td>
<td>C</td>
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<td>36</td>
<td></td>
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<tr>
<td>Fe/Zn or Fe/Cd 3D</td>
<td>D</td>
<td>24</td>
<td></td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 5A</td>
<td>5</td>
<td>A</td>
<td>6</td>
<td>48</td>
<td>24</td>
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<tr>
<td>Fe/Zn or Fe/Cd 5B</td>
<td>B</td>
<td>12</td>
<td></td>
<td>72</td>
<td>36</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 5C</td>
<td>C</td>
<td>48</td>
<td></td>
<td>120</td>
<td>72</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 5D</td>
<td>D</td>
<td>72</td>
<td></td>
<td>168</td>
<td>96</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 5E</td>
<td>E</td>
<td>12</td>
<td></td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 8A</td>
<td>8</td>
<td>A</td>
<td>6</td>
<td>96</td>
<td>48</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 8B</td>
<td>B</td>
<td>24</td>
<td></td>
<td>120</td>
<td>72</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 8C</td>
<td>C</td>
<td>72</td>
<td></td>
<td>168</td>
<td>120</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 8D</td>
<td>D</td>
<td>96</td>
<td></td>
<td>192</td>
<td>144</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 8E</td>
<td>E</td>
<td>24</td>
<td></td>
<td>120</td>
<td>72</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 12A</td>
<td>12</td>
<td>A</td>
<td>6</td>
<td>144</td>
<td>72</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 12B</td>
<td>B</td>
<td>24</td>
<td></td>
<td>192</td>
<td>96</td>
</tr>
<tr>
<td>Fe/Zn or Fe/Cd 12C</td>
<td>C</td>
<td>72</td>
<td></td>
<td>240</td>
<td>144</td>
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<td></td>
<td>264</td>
<td>168</td>
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<td>E</td>
<td>24</td>
<td></td>
<td>192</td>
<td>96</td>
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<tr>
<td>Fe/Zn or Fe/Cd 12F</td>
<td>F</td>
<td>196</td>
<td></td>
<td>340</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Low coating thickness impairs chromate adhesion and performance.

#### TABLE A1.2 Classification Code and Neutral Salt Spray Corrosion Protection Performance of Zinc-Cobalt Coatings

<table>
<thead>
<tr>
<th>Classification Code</th>
<th>Minimum Coating Thickness (µm)</th>
<th>Chromate Finish Designation</th>
<th>First Appearance of Zinc Alloy Corrosion Product (hour)</th>
<th>First Appearance of Red Rust (hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe/Zn-Co 5C</td>
<td>5</td>
<td>C</td>
<td>96</td>
<td>240</td>
</tr>
<tr>
<td>Fe/Zn-Co 5D</td>
<td></td>
<td>D</td>
<td>96</td>
<td>240</td>
</tr>
<tr>
<td>Fe/Zn-Co 5E</td>
<td></td>
<td>E</td>
<td>100</td>
<td>240</td>
</tr>
<tr>
<td>Fe/Zn-Co 5F</td>
<td></td>
<td>F</td>
<td>196</td>
<td>340</td>
</tr>
<tr>
<td>Fe/Zn-Co 8C</td>
<td>8</td>
<td>C</td>
<td>96</td>
<td>240</td>
</tr>
<tr>
<td>Fe/Zn-Co 8D</td>
<td></td>
<td>D</td>
<td>96</td>
<td>240</td>
</tr>
<tr>
<td>Fe/Zn-Co 8E</td>
<td></td>
<td>E</td>
<td>100</td>
<td>240</td>
</tr>
<tr>
<td>Fe/Zn-Co 8F</td>
<td></td>
<td>F</td>
<td>200</td>
<td>340</td>
</tr>
<tr>
<td>Fe/Zn-Co 12B</td>
<td>12</td>
<td>B</td>
<td>12</td>
<td>240</td>
</tr>
<tr>
<td>Fe/Zn-Co 12C</td>
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<td>C</td>
<td>96</td>
<td>400</td>
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<tr>
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<tr>
<td>Fe/Zn-Co 12F</td>
<td></td>
<td>F</td>
<td>196</td>
<td>500</td>
</tr>
</tbody>
</table>
X1. STANDARD ELECTRODEPOSITION PROCESSES

X1.1 Barrel-Plating Process—The preparation and metallic coating of threaded fasteners is usually accomplished by the barrel-plating process. In this process, quantities of an item are placed within a containment vessel, called a barrel. The barrel is designed to move the group of items, together, through each of the process steps, allowing ready ingress and egress of processing solutions and rinses. As the barrel is moved through the process steps, it is also rotated such that the individual items are constantly cascading over one another. This can damage the external threads of fasteners. The effect of thread damage is worse on heavy fine threaded fasteners than on light coarse threaded fasteners. In some of the process steps, notably the electrocleaning and electroplating steps, an electric current is applied to the group of items. The cascading action randomly exposes the surface of each individual piece to the process electrodes while also maintaining electrical continuity between all the parts. The local coating thickness on a part is a result of the electrical current density at that location. Therefore, the coating thickness on an individual screw or bolt tends to be greatest at the extremities (head and threaded tip). The extremities being the high current density areas receive the greatest coating thickness. In contrast, the center or recesses such as the

<table>
<thead>
<tr>
<th>Classification Code</th>
<th>Minimum Coating Thickness (µm)</th>
<th>Chromate Finish Designation</th>
<th>First Appearance of Zinc Alloy Corrosion Product (hour)</th>
<th>First Appearance of Red Rust (hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe/Zn-Ni 5B</td>
<td>5</td>
<td>B</td>
<td>20</td>
<td>150</td>
</tr>
<tr>
<td>Fe/Zn-Ni 5C</td>
<td></td>
<td>C</td>
<td>120</td>
<td>500</td>
</tr>
<tr>
<td>Fe/Zn-Ni 5D</td>
<td></td>
<td>D</td>
<td>180</td>
<td>750</td>
</tr>
<tr>
<td>Fe/Zn-Ni 5E</td>
<td></td>
<td>E</td>
<td>100</td>
<td>500</td>
</tr>
<tr>
<td>Fe/Zn-Ni 5B/F</td>
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<td>B/F</td>
<td>150</td>
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</tr>
<tr>
<td>Fe/Zn-Ni 5C/F</td>
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<td>C/F</td>
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<tr>
<td>Fe/Zn-Ni 5D/F</td>
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<td>D/F</td>
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<td>1000</td>
</tr>
<tr>
<td>Fe/Zn-Ni 5E/F</td>
<td></td>
<td>E/F</td>
<td>220</td>
<td>620</td>
</tr>
<tr>
<td>Fe/Zn-Ni 8B</td>
<td>8</td>
<td>B</td>
<td>20</td>
<td>240</td>
</tr>
<tr>
<td>Fe/Zn-Ni 8C</td>
<td></td>
<td>C</td>
<td>120</td>
<td>720</td>
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<tr>
<td>Fe/Zn-Ni 8D</td>
<td></td>
<td>D</td>
<td>180</td>
<td>960</td>
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<tr>
<td>Fe/Zn-Ni 8E</td>
<td></td>
<td>E</td>
<td>100</td>
<td>720</td>
</tr>
<tr>
<td>Fe/Zn-Ni 8B/F</td>
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<td>D/F</td>
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<tr>
<td>Fe/Zn-Ni 12B</td>
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<td>B</td>
<td>20</td>
<td>500</td>
</tr>
<tr>
<td>Fe/Zn-Ni 12C</td>
<td></td>
<td>C</td>
<td>120</td>
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<tr>
<td>Fe/Zn-Ni 12D</td>
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<td>Fe/Zn-Ni 12B/F</td>
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<tr>
<td>Fe/Zn-Ni 12C/F</td>
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<td>C/F</td>
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<td>1080</td>
</tr>
<tr>
<td>Fe/Zn-Ni 12D/F</td>
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<td>D/F</td>
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<td>1500</td>
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<tr>
<td>Fe/Zn-Ni 12E/F</td>
<td></td>
<td>E/F</td>
<td>220</td>
<td>1080</td>
</tr>
</tbody>
</table>

APPENDIXES

(Nonmandatory Information)

XI. STANDARD ELECTRODEPOSITION PROCESSES
bottom of the threads, which are the low current density areas, receive the lowest coating thickness. This phenomenon is accentuated with increasing length and decreasing diameter of the screw or bolt. The extremity-to-center coating thickness ratio increases with increasing length and decreasing diameter, but is also a function of process parameters such as plating solution chemistry and efficiency, anodic/cathodic efficiency, average current density and plating time.

X1.2 **Rack-Plating Process**—The preparation and metallic coating of threaded fasteners can be accomplished by the rack-plating process, particularly on large size fasteners where thread fit and/or damage is a concern, or for smaller size fasteners when it is economically feasible. In this process, quantities of an item are placed on a support, called a rack. The rack is designed to move the group of items, together, through each of the process steps, allowing ready ingress and egress of processing solutions and rinses. In some of the process steps, notably the electrocleaning and electroplating steps, an electric current is applied to the group of items. The electrical continuity is maintained between the parts by the rack itself. The average current density is usually low enough such that the extremity-to-center coating thickness ratio is much lower than with barrel-plating. The external thread damage is also minimized in comparison to barrel-plating due to the absence of tumbling.

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**X2. GUIDELINES FOR CHOOSING BETWEEN BARREL-PLATING AND RACK-PLATING**

X2.1 Table X2.1 indicates the recommended electroplating process for each size of externally threaded metric fasteners for all thickness classes in Table 2. For internally threaded fasteners barrel-plating is generally suitable.

**TABLE X2.1 Recommended Electroplating Process for Each Size of Externally Threaded Metric Fasteners**

<table>
<thead>
<tr>
<th>Diameter (D), (in.)</th>
<th>Length (L)</th>
<th>5D ≤ L ≤ 10D</th>
<th>10D &lt; L ≤ 20D</th>
<th>20D &lt; L ≤ 30D</th>
<th>L &gt; 30D</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1.6-M4</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>M5-M6</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>M8-M10</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>M12</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>M14</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>M16</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>M20</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>M24</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>M30-M100</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
</tbody>
</table>

**X3. COATING ACCOMMODATION TOLERANCES FOR EXTERNALLY AND INTERNALLY THREADED FASTENERS**

X3.1 Short screws and bolts are those with a length-to-diameter ratio equal to or less than 5. Long screws and bolts have a length-to-diameter ratio greater than 5 but less than 10. Special processing is normally required for bolts with a ratio greater than 10 in order to minimize the extremity-to-center thickness ratio.

X3.2 This specification does not impose maximum thickness values on high current density areas, where the coating thickness tends to be the greatest. On an externally threaded fastener this occurs at the threaded tip. Measuring coating thickness on the threaded portion of a fastener is possible but impractical for in-process quality control verification. For this reason the control mechanism specified in this document is by means of GO thread gauges. Nevertheless Table X3.1, which is supplied as an informative guideline, illustrates the maximum coating thickness permitted by the allowance for tolerance classes 6g and 4g6g.

**TABLE X3.1 Coating Accommodation Tolerances for Externally Threaded Class 6g and 4g6g Metric Fasteners**

<table>
<thead>
<tr>
<th>Thread Pitch, mm</th>
<th>Diameter, (in.)</th>
<th>Pitch Diameter Allowance for 6g and 4g6g Tolerance Positions, (µm)</th>
<th>Maximum Allowable Coating Thickness on Threaded Tip (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.35</td>
<td>M1.6</td>
<td>−19</td>
<td>4</td>
</tr>
<tr>
<td>0.4</td>
<td>M2</td>
<td>−19</td>
<td>4</td>
</tr>
<tr>
<td>0.45</td>
<td>M2.5</td>
<td>−20</td>
<td>5</td>
</tr>
<tr>
<td>0.5</td>
<td>M3</td>
<td>−20</td>
<td>5</td>
</tr>
<tr>
<td>0.6</td>
<td>M3.5</td>
<td>−21</td>
<td>5</td>
</tr>
<tr>
<td>0.7</td>
<td>M4</td>
<td>−22</td>
<td>5</td>
</tr>
<tr>
<td>0.8</td>
<td>M5</td>
<td>−24</td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>M6</td>
<td>−26</td>
<td>6</td>
</tr>
<tr>
<td>1.25</td>
<td>M8</td>
<td>−28</td>
<td>7</td>
</tr>
<tr>
<td>1.5</td>
<td>M10</td>
<td>−32</td>
<td>8</td>
</tr>
<tr>
<td>1.75</td>
<td>M12</td>
<td>−34</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>M14, M16</td>
<td>−38</td>
<td>9</td>
</tr>
<tr>
<td>2.5</td>
<td>M20</td>
<td>−42</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>M24</td>
<td>−48</td>
<td>12</td>
</tr>
<tr>
<td>3.5</td>
<td>M30</td>
<td>−53</td>
<td>13</td>
</tr>
<tr>
<td>4</td>
<td>M36</td>
<td>−60</td>
<td>15</td>
</tr>
<tr>
<td>4.5</td>
<td>M42</td>
<td>−63</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>M48</td>
<td>−71</td>
<td>17</td>
</tr>
<tr>
<td>5.5</td>
<td>M56</td>
<td>−75</td>
<td>18</td>
</tr>
<tr>
<td>6</td>
<td>M64, M72, M80, M90, M100</td>
<td>−80</td>
<td>20</td>
</tr>
</tbody>
</table>

---

**NOTE**: X3.1—The following information is based on ASME B1.13M. That standard should be consulted for more detailed information.
X3.3 Size limits for standard tolerance classes 6g and 4g6g apply prior to coating. The external thread allowance may thus be used to accommodate the coating thickness on threaded fasteners, provided the maximum coating thickness is no more than ¼ of the allowance (see Fig. X3.1). Thus, threads after coating are subject to acceptance using a class 6h GO gauge for plated 6g class external threads and 4h6h GO gauge for plated 4g6g class external threads respectively. Class 6g and 4g6g shall be used as respective NOT-GO gauges.

X3.4 In certain cases size limits must be adjusted, within the tolerances, prior to coating, in order to insure proper thread fit. This applies to the following cases:

X3.4.1 Standard internal threads, because they provide no allowance for coating thickness.

X3.4.2 Where the external thread has no allowance, such as in class h external threads.

X3.4.3 Where allowance must be maintained after coating for trouble free thread fit.

X3.5 Table X3.1 provides maximum coating thickness values based only on the allowance for external thread tolerance classes 6g and 4g6g. It assumes that the external thread pitch diameter is at the maximum and that the internal thread pitch diameter is at the minimum of the tolerance.
X4. APPLICATION REQUIREMENTS

X4.1 Cleaning of Basis Metal—Thorough cleaning of the basis metal is essential in order to ensure satisfactory adhesion, appearance and corrosion resistance of the coating.

X4.2 Hydrogen Embrittlement Risk Management:

X4.2.1 Process Considerations—The following are some general recommendations for managing the risk of hydrogen embrittlement. For more detailed information refer to IFI-142 “Hydrogen Embrittlement Risk Management”.

X4.2.1.1 Clean the fasteners in non-cathodic alkaline solutions and in inhibited acid solutions.

X4.2.1.2 Use abrasive cleaners for fasteners having a hardness of 40 HRC or above and case hardened fasteners.

X4.2.1.3 Manage anode/cathode surface area and efficiency, resulting in proper control of applied current densities. High current densities increase hydrogen charging.

X4.2.1.4 Use high efficiency plating processes such as zinc chloride or acid cadmium

X4.2.1.5 Control the plating bath temperature to minimize the use of brighteners.

X4.2.1.6 Select raw materials with a low susceptibility to hydrogen embrittlement by controlling steel chemistry, microstructure and mechanical properties.

X4.2.2 Process Control Verification—Test Method F 1940 should be used as a test method for process control to minimize the risk of hydrogen embrittlement. Periodic inspections should be conducted according to a specified test plan. The test plan should be designed based upon the specific characteristics of a process, and upon agreement between the purchaser and the manufacturer. The testing frequency should initially establish and subsequently verify over time, the ability of a process to produce parts that do not have the potential for hydrogen embrittlement.
Standard Specification for
Silicon Nitride Bearing Balls

This standard is issued under the fixed designation F 2094; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope
1.1 This specification covers the establishment of the basic quality, physical/mechanical property, and test requirements for silicon nitride balls Classes I, II, and III to be used for ball bearings and specialty ball applications.
1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents
2.1 Order of Precedence:
2.1.1 In the event of a conflict between the test of this document and the references herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.
2.2 ASTM Standards:
C 373 Test for Water Absorption, Bulk Density, Apparent Porosity, and Apparent Specific Gravity of Fired Whiteware Products
C 1161 Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature
C 1198 Test Method for Dynamic Young’s Modulus, Shear Modulus, and Poisson’s Ratio for Advanced Ceramics by Sonic Resonance
C 1239 Practice for Reporting Uniaxial Strength Data and Estimating Weibull Distribution Parameters for Advanced Ceramics
C 1327 Test Method for Vickers Indentation Hardness of Advanced Ceramics
C 1421 Test Methods for Determination of Fracture Toughness of Advanced Ceramics at Ambient Temperatures
E 165 Test Method for Liquid Penetrant Examination
E 384 Test Method for Microindentation Hardness of Materials
E 831 Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis
E 1417 Practice for Liquid Penetrant Examination
2.3 ANSI Standard:
ANSI/ASQC Z1.4 Sampling Procedures and Tables for Inspection by Attributes
2.4 ABMA Standards:
STD 1 Terminology for Anti-Friction Ball and Roller Bearings and Parts
STD 10 Metal Balls
2.5 ASME Standard:
B 46.1 Surface Texture (Surface Roughness, Waviness, and Lay)
2.6 DIN Standards:
5401 Rolling Bearings; Balls of Through-Hardening Rolling Bearing Steel, Part 1
5401 Rolling Bearings; Balls of Through-Hardening Rolling Bearing Steel, Part 2
2.7 ISO Standards:
3290 Rolling Bearings, Bearing Parts, Balls for Rolling Bearings
4505 Hardmetals—Metallographic Determination of Porosity and Uncombined Carbon
2.8 JIS Standards:
R 1601 Testing Method for Flexural Strength (Modulus of Rupture) of High Performance Ceramics
R 1602 Testing Method for Elastic Modulus of High Performance Ceramics
R 1603 Methods for Chemical Analysis of Fine Silicon Nitride Powders for Fine Ceramics
R 1607 Testing Method for Fracture Toughness of High Performance Ceramics

1 This specification is under the jurisdiction of ASTM Committee F34 on Rolling Element Bearings and is the direct responsibility of Subcommittee F34.01 on Rolling Element. Current edition approved Dec. 1, 2003. Published December 2003. Originally approved in 2001. Last previous edition approved in 2003 as F 2094 – 03.
2 For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard’s Document Summary page on the ASTM website.
3 Application for copies should be addressed to the American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036.
4 Application for copies should be addressed to the American Bearing Manufacturer’s Association, 1200 19th Street NW, Suite 300, Washington, DC 20036-2401.
5 Application for copies should be addressed to the American Society of Mechanical Engineers, 345 East Street, New York, NY 10017.
6 Application for copies should be addressed to the Deutsches Institut Für Normung (German Standards Institute), Burggrafenstrasse 6, D 10787 Berlin, Germany.
7 Application for copies should be addressed to the Japanese Standards Association, 1-24 Akasaka 4 chome, Minato-ku, Tokyo, 107 Japan.
3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 ball diameter variation (Vdws)—ball diameter variation is the difference between the largest and smallest diameter measured on the same ball.

3.1.2 ball gage (S)—prescribed small amount by which the lot mean diameter should differ from nominal diameter, this amount being one of an established series of amounts. A ball gage, in combination with the ball grade and nominal ball diameter, should be considered as the most exact ball size specification to be used by a customer for ordering purposes.

3.1.3 ball gage deviation (ΔS)—difference between the lot mean diameter and the sum of the nominal diameter and the ball gage.

3.1.4 ball grade (G)—specific combination of dimensional form and surface roughness tolerances. A ball grade is designated by a grade number followed by the letter “C” indicating Silicon Nitride Ceramic.

3.1.5 blank lot—single group of same-sized ball blanks processed together from one material lot through densification.

3.1.6 deviation from spherical form (ΔRw)—greatest radial distance in any radial plane between a sphere circumscribed around the ball surface and any point on the ball surface.

3.1.7 finish lot—single group of same-sized balls (which may be derived from multiple blank lots of the same material lot) processed together through finishing.

3.1.8 lot diameter variation (Vdwl)—difference between the mean diameter of the largest ball and that of the smallest ball in the lot.

3.1.9 lot mean diameter (Dwml)—arithmetic mean of the mean diameter of the largest ball and that of the smallest ball in the lot.

3.1.10 material lot—single process lot of silicon nitride raw powder received from a material supplier.

3.1.11 mean diameter of a ball (Dwm)—arithmetic mean of the largest and smallest actual diameters of the ball.

3.1.12 nominal diameter (Dw)—size ordered that is the basis to which the nominal diameter tolerances apply. The nominal diameter is specified in inches or millimeters (decimal form).

3.1.13 nominal diameter tolerance—maximum allowable deviation from true specified nominal diameter for the indicated grade.

3.1.14 single diameter of a ball (Dws)—the distance between two parallel planes tangent to the surface of the ball.

3.1.15 surface roughness (Ra)—surface irregularities with relative small spacings, which usually include irregularities resulting from the method of manufacture being used or other influences, or both.

3.1.16 unit container—container identified as containing balls from the same manufacture lot of the same composition, grade, and nominal diameter, and within the allowable diameter variation per unit container for the specified grade.

4. Classification

4.1 Silicon nitride materials for bearing and specialty ball applications are specified according to the following material classes (see Appendix X1 for typical current applications):

4.1.1 Class I—Highest grade of material in terms of properties and microstructure. Suitable for use in the most demanding applications. This group adds high reliability and durability for extreme performance requirements.

4.1.2 Class II—General class of material for most bearing and specialty ball applications. This group addresses the concerns of ball defects as is relative to fatigue life, levels of torque, and noise.

4.1.3 Class III—Lower grade of material for low duty applications only. This group of applications primarily takes advantage of silicon nitride material properties. For example: Light weight, chemical inertert, lubricant life extension due to dissimilarity with race materials, etc.

5. Ordering Information

5.1 Acquisition documents should specify the following:

5.1.1 Title, number, and date of this specification.

5.1.2 Class, grade, and size (see 4.1, 8.6, and 8.7).
6. Material

6.1 Unless otherwise specified, physical and mechanical property requirements will apply to all material classes.

6.2 Silicon nitride balls should be produced from either silicon nitride powder having the compositional limits listed in Table 1 or from silicon metal powder, which after nitridation complies with the compositional limits listed in Table 1.

6.3 Composition is measured in weight percent. Testing shall be carried out by a facility qualified and approved by the supplier. Specific equipment, tests, and/or methods are subject to agreement between suppliers and their customers.

6.4 The following compounds may be added to promote densification and/or enhance product performance and quality. The following may be added as oxides, nitrides, oxynitrides, or mixtures:

6.4.1 Aluminum,
6.4.2 Magnesium,
6.4.3 Barium,
6.4.4 Lanthanum,
6.4.5 Yttrium,
6.4.6 Calcium, and
6.4.7 Other rare earths.

6.5 The following may be added as nitrides, oxynitrides, or carbonitrides:

6.5.1 Titanium,
6.5.2 Tantalum, and
6.5.3 Zirconium.

6.6 Aluminum silicon oxynitrides (aluminum nitride polytypes) may be added to promote densification.

6.7 Precautions should be taken to minimize contamination by foreign materials during all stages of processing up to and including densification.

6.8 A residual content of up to 2% tungsten carbide from powder processing is allowable.

6.9 Final composition shall meet and be reported according to the specification of the individual supplier.

6.10 Notification will be made upon process changes.

6.11 Specific requirements such as specific material grade designation, physical/mechanical property requirements (for example, density) or quality or testing requirements shall be established by specific application. The special requirements shall be in addition to the general requirements established in this specification.

6.12 Typical mechanical properties will fall within the range listed in Table 2. Individual requirements may have tighter ranges. The vendor shall certify that the silicon nitride material supplied has physical and mechanical properties within the range given in Table 2. In the case of properties indicated by (+), the provision of the data is not mandatory.

<table>
<thead>
<tr>
<th>TABLE 1 Compositional Limits^a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constituents</td>
</tr>
<tr>
<td>Silicon nitride</td>
</tr>
<tr>
<td>Free silicon</td>
</tr>
<tr>
<td>Carbon</td>
</tr>
<tr>
<td>Iron</td>
</tr>
</tbody>
</table>

^a Other impurities or elements such as sodium, potassium, chlorine, etc. individually shall not exceed 0.02 wt % max.

7. Physical Properties

7.1 The following physical properties shall be measured, at a minimum, on each material lot.

7.1.1 Average values for room temperature rupture strength (bend strength/modulus of rupture) for a minimum of 20 individual determinations shall exceed the minimum values given in Table 3. Either 3-point or 4-point test methods may be used for flexural strength, which should be measured in accordance with Test Method C 1161 (size B), CEN EN 843-1, or JIS R 1601. Weibull modulus for each test series shall also exceed the minimum permitted values given in Table 3. If a sample set of specimens for a material lot does not meet the Weibull modulus requirement in Table 3, then a second sample set may be tested to establish conformance.

7.1.2 The hardness (HV) shall be determined by the Vickers method (see Annex A1) using a load of at least 5 kg but not exceeding 20 kg. Fracture resistance shall be measured by

<table>
<thead>
<tr>
<th>TABLE 2 Typical Mechanical Properties^a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Properties</td>
</tr>
<tr>
<td>Density, g/cc (lb/ft³)</td>
</tr>
<tr>
<td>Elastic modulus, GPa (ksi)</td>
</tr>
<tr>
<td>Poisson’s ratio</td>
</tr>
<tr>
<td>Thermal conductivity, W/m-°K (Btu/h-ft-°F) – @ 20°C (room temp.)</td>
</tr>
<tr>
<td>Specific heat, J/kg-°K (Btu/1bm-°F)</td>
</tr>
<tr>
<td>Coefficient of thermal expansion, ×10⁶/°C (room temp. to 500°C)</td>
</tr>
<tr>
<td>+ Resistivity, Ohm-m</td>
</tr>
<tr>
<td>+ Compressive strength, MPa (ksi)</td>
</tr>
</tbody>
</table>

^a Special material data should be obtained from individual suppliers.

<table>
<thead>
<tr>
<th>TABLE 3 Minimum Values for Mean Flexural Strength and Weibull Modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse-rupture strength^a</td>
</tr>
<tr>
<td>3 point</td>
</tr>
<tr>
<td>α₃,₄₀(r₃₃,₃₀)</td>
</tr>
<tr>
<td>Transverse-rupture strength^a</td>
</tr>
<tr>
<td>4-point</td>
</tr>
</tbody>
</table>

^a The Flexural strength equivalents are based on Weibull volume or surface scaling using the value of m for each cell and are rounded to the nearest 5 MPa. α₃₄₀₃₀ = denotes the flexure strength, n = 3 or 4 point, on spans of size L. α₄₄₀₃₀ = 660 MPa means the four point flexure strength, on 40 mm spans is 660 MPa as per Test Method C 1161 (size B) and CEN EN 843-1. α₄₃₀₃₀ = 700 MPa means the four point flexure strength, on 30 mm spans is 700 MPa as per JIS R1601.
either an indentation technique (see Annex A1) or by a standard fracture toughness test method. Average values for hardness and fracture resistance shall exceed the minimum of values for the specified material class given in Table 4.

7.1.3 Microstructure constituents visible at magnification in the range ×100 to ×200 shall not exceed the maximum values given in Table 5 for the specified material class.

7.1.4 The number of ceramic metallic or mixed inclusions observed in transverse sections shall not exceed the limits given in Table 6.

7.1.5 Macrostructure variation visible at 1× on a polished section is not permissible.

7.1.6 Density variation from the mean value of a sample of at least 10 pieces taken from a batch of components manufactured under the same conditions shall not exceed the values for 3 times the standard deviation (3×sigma) given in Table 7, according to the volume of the component after any finishing operations and the specified material class. Density variation testing will apply to all lots of material for the initial 50 lots. If consistent results are achieved, the testing will be optional.

8. Inspection and Verification

8.1 The intent of this section is to list potential defects and methods of inspection of finished balls. As the spectrum of applications for silicon nitride balls is very broad, this is not intended to define requirements, but to highlight these points. The type of defects, methods of inspection, and limits should be agreed upon by the customer and vendor to meet the specific requirements for a given application.

8.2 Unless otherwise specified, all dimensional and form inspections shall be performed under the following conditions:

8.2.1 Temperature—Room ambient 20° to 25°C (68° to 77°F).

8.2.2 Humidity—50 % relative, maximum.

8.3 Unless otherwise required, product shall be capable of passing acceptance inspection in accordance with ANSI/ASQC Z1.4 as specified in Table 8.

8.4 Certain manufacturer to manufacturer or lot to lot variation in color is acceptable. Color variation within a single ball should be investigated per 8.5.

8.5 There may exist in silicon nitride bearing balls the defects listed in Section 8.5.1, which may be inspected for using the methods in 8.5.2 as required.

8.5.1 Types of Defects:

8.5.1.1 Inclusions;

8.5.1.2 Porosity;

8.5.1.3 Pits, scratches, nicks, scuffs;

8.5.2 Cracks or linear indications; and

8.5.1.4 Color variation.

8.5.2 Methods of Inspection:

8.5.2.1 Visual white light (unaided eye and magnification-aided eye);

8.5.2.2 Black light (unaided eye and magnification-aided eye);

8.5.2.3 Fluorescent penetrant inspection (FPI) (unaided eye and magnification-aided eye); and

8.5.2.4 Other methods as mutually agreed upon.

8.5.3 Density variation from the mean value of a sample of at least 10 pieces taken from a batch of components manufactured under the same conditions shall not exceed the values for 3 times the standard deviation (3×sigma) given in Table 7, according to the volume of the component after any finishing operations and the specified material class. Density variation testing will apply to all lots of material for the initial 50 lots. If consistent results are achieved, the testing will be optional.

8.5.4 Certain manufacturer to manufacturer or lot to lot variation in color is acceptable. Color variation within a single ball should be investigated per 8.5.

8.5.5 There may exist in silicon nitride bearing balls the defects listed in Section 8.5.1, which may be inspected for using the methods in 8.5.2 as required.

8.5.6 Cracks or linear indications; and

8.5.1.4 Color variation.

8.5.2 Methods of Inspection:

8.5.2.1 Visual white light (unaided eye and magnification-aided eye);

8.5.2.2 Black light (unaided eye and magnification-aided eye);

8.5.2.3 Fluorescent penetrant inspection (FPI) (unaided eye and magnification-aided eye); and

8.5.2.4 Other methods as mutually agreed upon.
8.5.2.4 Ultrasonic Inspection (The following methods are currently in development and may require extensive evaluation to be applicable):

(1) Resonant inspection (resonant ultrasound spectroscopy),

(2) Rayleigh wave, and

(3) Acoustic microscopy.

8.6 Dimensional and Form.

8.6.1 Tolerances by Grade for Individual Balls and Tolerances by Grade for Lots of Balls—Tests shall be in accordance with Tables 8-10. A minimum of three measurements shall be taken in random orientations on each sample ball examined.

8.6.2 Acceptable methods of determining errors in spherical forms include the following: roundness measuring equipment procedures and Vee Block examination procedure. Explanation and details of these methods shall be as indicated in ABMA STD-10. Tests shall be in accordance with Tables 8 and 9.

8.7 The nominal diameter of the balls shall be as specified in the contract or purchase order. Tolerance limits for size variations and form deviations shall be in accordance with Tables 9 and 10.

8.8 The surface roughness of the balls shall not exceed the value specified in Table 11 for the specified grade. Surface roughness shall be in accordance with ASME B 46.1.

9. Certificates of Quality and Material Certification (This section contains information of a general or explanatory nature which may be helpful but is not mandatory.)

9.1 When specified in the contract or purchase order, certificates of quality (conformance) supplied by the manufacturer of the balls may be furnished in lieu of actual performance of such testing by the manufacturer, provided the lot identity has been maintained and can be demonstrated to the customer. The certificate may include:

9.1.1 Name of the customer,

9.1.2 Contract or purchase order number,

9.1.3 Name of the manufacturer or supplier,

9.1.4 NSN (National Stock Number) item identification number,

9.1.5 Name of the material,

9.1.6 Lot number,

9.1.7 Lot size,

9.1.8 Sample size,

9.1.9 Date of testing,

9.1.10 Test method,

9.1.11 Individual test results, and

9.1.12 Specification requirements.

9.2 When specified in the contract or purchase order, a certified report shall be available for review or when requested submitted by the manufacturer or supplier on each lot of balls. The report may contain the following:

9.2.1 Contract or purchase order number,

9.2.2 Material specification number and revision,

9.2.3 Size,

9.2.4 Quantity,

9.2.5 Batch identification code,

9.2.6 Chemical analysis of silicon nitride that meets the blank manufacturer’s specification (optional),

9.2.7 Flexural Strength (optional),

9.2.8 Materials properties as listed in Table 2 of this specification (optional),

9.2.9 Hardness,

9.2.10 Fracture toughness, and

9.2.11 Microstructure ratings.

9.2.12 A statement that this material has been processed and tested in accordance with this specification (latest revision) and/or approved material specifications.

9.2.13 Contract or purchase order requirements other than those specified within this specification will have authority over this document.

10. Packaging

10.1 For acquisition purposes, the packaging requirements shall be as specified in the contract or order.

10.2 Preservatives are not required.

10.3 Special Handling. It is recommended that for Class I applications, balls 3⁄8 inch in diameter and greater should be packaged to prevent ball-to-ball contact.

11. Keywords

11.1 ball bearings; bearing balls; ceramic; silicon nitride; Si₃N₄; precision balls
A1. VICKER’S HARDNESS AND NIIHARA’S TOUGHNESS MEASUREMENTS

A1.1 Measurements for hardness and toughness are made on a polished cross-section.

A1.2 Indentations for toughness measurement are made using a Vicker’s indenter under the following conditions:

- Load: 20 kgf
- Dwell Time: 30 s

A1.3 Hardness and toughness are calculated as follows (see Fig. A1.1):

A1.3.1 Measure both diagonals of each hardness impression as “2a” values according to orientation except when impressions are placed on separate pieces.

A1.3.2 Measure visible tip-to-tip crack lengths associated with the hardness impressions as “2c” values according to orientation except when impressions are placed on separate pieces.

A1.3.3 Calculate the mean values of $2a = (2a_1 + 2a_2)/2$ and $2c = (2c_1 + 2c_2)/2$ in micron ($\mu$m).

A1.3.4 Calculate the Vickers hardness value as follows:

$$HV = 1.854,400 \frac{P}{(2a)^2}$$

where:
- $HV$ = Vicker’s hardness number. The symbol should be written with the indentation load in kilograms denoted in parentheses (for example, HV(20) for a 20kgf load.)
- $P$ = the applied load in kilogram force (kgf).
- $a(2a/2)$ = the mean half diagonal value in microns ($\mu$m).

A1.3.5 Calculate the indentation fracture resistance by Niihara’s method as follows:

$$IFR = 10.4 \left(\frac{E}{P} \right)^{0.6} \left(\frac{a}{c}\right)^{1.5}$$

where:
- $IFR$ = the indentation fracture resistance in megapascals–square root meter (Mpa-m$^{0.5}$)
- $E$ = the elastic modulus in gigapascals (Gpa).
- $P$ = the applied load in kilogram force (kgf).
- $a$ = the mean half diagonal value in microns ($\mu$m).
- $c$ = the mean half tip-to-tip crack length in microns ($\mu$m).

A1.4 Alternative formulas or calibration constants for
indentation fracture resistance may be used by mutual agreement of customer and vendor.

Note A1.1—The within-lab (repeatability) consistency of results by this method may be acceptable, but the between-laboratory (reproducibility) consistency is often poor due to variations in the interpretation of the crack length arising from microscopy limitations as well as operator experience or subjectivity.
APPENDIX

(Nonmandatory Information)

X1. Examples of Typical Current Markets (Arrows Indicate Potential Overlap)

<table>
<thead>
<tr>
<th>Class</th>
<th>Grade 2, 3</th>
<th>Grade 5</th>
<th>Grade 10, 16</th>
<th>Grade 24, 48</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>High Speed</td>
<td>Lox</td>
<td>Critical</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Momentum</td>
<td>Pump</td>
<td>Aircraft</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Device</td>
<td>Mainshaft</td>
<td>Parts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Space</td>
<td>Bearing</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mechanism</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aircraft</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Instrument</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class II</td>
<td>Turbo</td>
<td>Vacuum</td>
<td>Electric</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Molecular</td>
<td>Equipment</td>
<td>Motors</td>
<td></td>
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<tr>
<td></td>
<td>Pump</td>
<td></td>
<td>Med/Low</td>
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</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td>Precision</td>
<td></td>
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<tr>
<td></td>
<td>Performance</td>
<td></td>
<td>Radial Bearing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Radial</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Bearing</td>
<td></td>
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<tr>
<td></td>
<td>Drill</td>
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<tr>
<td></td>
<td>Instrument</td>
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<td></td>
<td>Screw</td>
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<tr>
<td></td>
<td>Aerospace</td>
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<td></td>
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<tr>
<td>Class III</td>
<td>Sports &amp;</td>
<td>Food</td>
<td>Mechanical</td>
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<td></td>
<td>Recreation</td>
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<td>Devices</td>
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</tbody>
</table>

FIG. X1.1 Examples of Typical Current Markets (Arrows Indicate Potential Overlap)

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Designation: F 2094 – 03a

Standard Specification for Silicon Nitride Bearing Balls

This standard is issued under the fixed designation F 2094; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the establishment of the basic quality, physical/mechanical property, and test requirements for silicon nitride balls Classes I, II, and III to be used for ball bearings and specialty ball applications.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 The following government interest activity codes may be found in the Department of Defense, Standardization Directory, SD-1.2

1 This specification is under the jurisdiction of ASTM Committee F34 on Rolling Element Bearings and is the direct responsibility of Subcommittee F34.01 on Rolling Element.

2. Referenced Documents

2.1 Order of Precedence:

2.1.1 In the event of a conflict between the text of this document and the references herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.2 ASTM Standards: ²

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of Defense Standardization Directory, SD-1, may be found at: http://assist.daps.dla.mil/online/start/. ASTM Standards volume information, refer to the standard’s Document Summary page on the ASTM website.
C 373 Test for Water Absorption, Bulk Density, Apparent Porosity, and Apparent Specific Gravity of Fired Whiteware Products
C 1161 Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature
C 1198 Test Method for Dynamic Young’s Modulus, Shear Modulus, and Poisson’s Ratio for Advanced Ceramics by Sonic Resonance
C 1239 Practice for Reporting Uniaxial Strength Data and Estimating Weibull Distribution Parameters for Advanced Ceramics
C 1327 Test Method for Vickers Indentation Hardness of Advanced Ceramics
C 1421 Test Methods for Determination of Fracture Toughness of Advanced Ceramics at Ambient Temperatures
E 165 Test Method for Liquid Penetrant Examination
E 384 Test Method for Microindentation Hardness of Materials
E 831 Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis
E 1417 Practice for Liquid Penetrant Examination
2.3 ANSI Standard:
ANSI/ASQC Z1.4 Sampling Procedures and Tables for Inspection by Attributes
2.4 ABMA Standards:
STD 1 Terminology for Anti-Friction Ball and Roller Bearings and Parts
STD 10 Metal Balls
2.5 ASME Standard:
B 46.1 Surface Texture (Surface Roughness, Waviness, and Lay)
2.6 DIN Standards:
5401 Rolling Bearings: Balls of Through-Hardening Rolling Bearing Steel, Part 1
5401 Rolling Bearings: Balls of Through-Hardening Rolling Bearing Steel, Part 2
2.7 ISO Standards:
3290 Rolling Bearings, Bearing Parts, Balls for Rolling Bearings
4505 Hardmetals—Metallographic Determination of Porosity and Uncombined Carbon
2.8 JIS Standards:
R 1601 Testing Method for Flexural Strength (Modulus of Rupture) of High Performance Ceramics
R 1602 Testing Method for Elastic Modulus of High Performance Ceramics
R 1603 Methods for Chemical Analysis of Fine Silicon Nitride Powders for Fine Ceramics
R 1607 Testing Method for Fracture Toughness of High Performance Ceramics
R 1610 Testing Method for Vicker’s Hardness of High Performance Ceramics
R 1611 Testing Methods of Thermal Diffusivity, Specific Heat Capacity and Thermal Conductivity for High Performance Ceramics by Laser Flash Method
R 1618 Measuring Method of Thermal Expansion of Fine Ceramics by Thermomechanical Analysis
R 1624 Weibull Statistics of Strength Data for Fine Ceramics
2.9 CEN Standards:
EN 843-1 Advanced Technical Ceramics—Monolithic Ceramics—Mechanical Properties at Room Temperature, Part 1. Determination of Flexural Strength
EN 843-2 Advanced Technical Ceramics—Monolithic Ceramics—Mechanical Properties at Room Temperature, Part 2 Determination of Elastic Moduli
ENV 843-5 Advanced Technical Ceramics—Monolithic Ceramics—Mechanical Properties at Room Temperature, Part 5. Statistical Analysis

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1 Application for copies should be addressed to the American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036.
2 Application for copies should be addressed to the American Bearing Manufacturer’s Association, 1200 19th Street NW, Suite 300, Washington, DC 20036-2401.
3 Application for copies should be addressed to the American Society of Mechanical Engineers, 345 East Street, New York, NY 10017.
4 Application for copies should be addressed to the Deutsches Institut Für Normung (German Standards Institute), Burggrafenstrasse 6, D 10787 Berlin, Germany.
5 Application for copies should be addressed to the Japanese Standards Association, 1-24 Akasaka 4 chome, Minato-ku, Tokyo, 107 Japan.
6 Application for copies should be addressed to the British Standards Institute, 35 West 43rd Street, 4th Floor, New York, NY 10036, 389 Chiswick High Road, London, W4 4AL, UK.
3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 ball diameter variation (Vdws)—ball diameter variation is the difference between the largest and smallest diameter measured on the same ball.

3.1.2 ball gage (S)—prescribed small amount by which the lot mean diameter should differ from nominal diameter, this amount being one of an established series of amounts. A ball gage, in combination with the ball grade and nominal ball diameter, should be considered as the most exact ball size specification to be used by a customer for ordering purposes.

3.1.3 ball gage deviation (ΔS)—difference between the lot mean diameter and the sum of the nominal diameter and the ball gage.

3.1.4 ball grade (G)—specific combination of dimensional form and surface roughness tolerances. A ball grade is designated by a grade number followed by the letter “C” indicating Silicon Nitride Ceramic.

3.1.5 nominal diameter—size ordered that is the basis to which the nominal diameter tolerances apply. The nominal diameter is specified in inches or millimeters (decimal form).

3.1.6 nominal diameter tolerance—maximum allowable deviation from true specified nominal diameter for the indicated grade.

3.1.7 blank lot—single group of same-sized ball blanks processed together from one material lot through densification.

3.1.8 deviation from spherical form (ΔRw)—greatest radial distance in any radial plane between a sphere circumscribed around the ball surface and any point on the ball surface.

3.1.9 lot mean diameter (Dwml)—arithmetic mean of the mean diameter of the largest ball and that of the smallest ball in the lot.

3.1.10 lot diameter variation (Vdwl)—difference between the mean diameter of the largest ball and that of the smallest ball in the lot.

3.1.11 lot mean diameter (Dwm)—arithmetic mean of the largest and the smallest actual single diameters of the ball.

3.1.12 nominal diameter (Dw)—size ordered that is the basis to which the nominal diameter tolerances apply. The nominal diameter is specified in inches or millimeters (decimal form).

3.1.13 nominal diameter tolerance—maximum allowable deviation from true specified nominal diameter for the indicated grade.

3.1.14 nominal size single diameter of a ball (Dws)—size that is used for the distance between two parallel planes tangent to the purpose surface of general identification, for example, 1/16, 1/8, etc., the ball.

3.1.15 specific diametersurface roughness (Ra)—diameter marked on—surface irregularities with relative small spacings, which usually include irregularities resulting from the unit container and expressed in the grade standard marking increment nearest to the average diameter method of the balls in the container or manufacture being used or other influences, or both.

3.1.16 unit container—container identified as containing balls from the same manufacture lot of the same composition, grade, and nominal diameter, and within the allowable diameter variation per unit container for the specified grade.

4. Classification

4.1 Silicon nitride materials for bearing and specialty ball applications are specified according to the following material classes (see Appendix X1 for typical current applications):

4.1.1 Class I—Highest grade of material in terms of properties and microstructure. Suitable for use in the most demanding applications. This group adds high reliability and durability for extreme performance requirements.

4.1.2 Class II—General class of material for most bearing and specialty ball applications. This group addresses the concerns of ball defects as it relates to fatigue life, levels of torque, and noise.

4.1.3 Class III—Lower grade of material for low duty applications only. This group of applications primarily takes advantage of silicon nitride material properties. For example: Light weight, chemical inertness, lubricant life extension due to dissimilarity with race materials, etc.

5. Ordering Information

5.1 Acquisition documents should specify the following:

5.1.1 Title, number, and date of this specification.

5.1.2 Class, grade, and size (see 4.1, 8.6, and 8.7).

6. Material

6.1 Unless otherwise specified, physical and mechanical property requirements will apply to all material classes.
6.2 Silicon nitride balls should be produced from either silicon nitride powder having the compositional limits listed in Table 1 or from silicon metal powder, which after nitridation complies with the compositional limits listed in Table 1.

6.3 Composition is measured in weight percent. Testing shall be carried out by a facility qualified and approved by the supplier. Specific equipment, tests, and/or methods are subject to agreement between suppliers and their customers.

6.4 The following compounds may be added to promote densification and/or enhance product performance and quality. The following may be added as oxides, nitrides, oxynitrides, or mixtures:

6.4.1 Aluminum,
6.4.2 Magnesium,
6.4.3 Barium,
6.4.4 Lanthanum,
6.4.5 Yttrium,
6.4.6 Calcium, and
6.4.7 Other rare earths.

6.5 The following may be added as nitrides, oxynitrides, or carbonites:

6.5.1 Titanium,
6.5.2 Tantalum, and
6.5.3 Zirconium.

6.6 Aluminum silicon oxynitrides (aluminum nitride polytypes) may be added to promote densification.

6.7 Precautions should be taken to minimize contamination by foreign materials during all stages of processing up to and including densification.

6.8 A residual content of up to 2% tungsten carbide from powder processing is allowable.

6.9 Final composition shall meet and be reported according to the specification of the individual supplier.

6.10 Notification will be made upon process changes.

6.11 Specific requirements such as specific material grade designation, physical/mechanical property requirements (for example, density) or quality or testing requirements shall be established by specific application. The special requirements shall be in addition to the general requirements established in this specification.

6.12 Typical mechanical properties will fall within the range listed in Table 2. Individual requirements may have tighter ranges. The vendor shall certify that the silicon nitride material supplied has physical and mechanical properties within the range given in Table 2. In the case of properties indicated by (+), the provision of the data is not mandatory.

7. Physical Properties

7.1 The following physical properties shall be measured, at a minimum, on each material lot.

7.1.1 Average values for room temperature rupture strength (bend strength/modulus of rupture) for a minimum of 20 individual determinations shall exceed the minimum values given in Table 3. Either 3-point or 4-point test methods may be used for flexural strength, which should be measured in accordance with Test Method C 1161 (size B), CEN 843-5, or JIS R 1601. Weibull modulus for each test series shall also exceed the minimum permitted values given in Table 3. If a sample set of specimens for a material lot does not meet the Weibull modulus requirement in Table 3, then a second sample set may be tested to establish conformance.

7.1.2 The hardness (HV) shall be determined by the Vickers method (see Annex A1) using a load of at least 5 kg but not exceeding 20 kg. Fracture resistance shall be measured by either an indentation technique (see Annex A1) or by a standard fracture toughness test method. Average values for hardness and fracture resistance shall exceed the minimum of values for the specified material class given in Table 4.

7.1.3 Microstructure constituents visible at magnification in the range \(3 \times 100\) to \(3 \times 200\) shall not exceed the maximum values given in Table 5 for the specified material class.

7.1.4 The number of ceramic metallic or mixed inclusions observed in transverse sections shall not exceed the limits given in Table 6.

7.1.5 Macrostructure variation visible at 1× on a polished section is not permissible.

7.1.6 Density variation from the mean value of a sample of at least 10 pieces taken from a batch of components manufactured under the same conditions shall not exceed the values for 3 times the standard deviation (3 × sigma) given in Table 7, according to the volume of the component after any finishing operations and the specified material class. Density variation testing will apply to all lots of material for the initial 50 lots. If consistent results are achieved, the testing will be optional.

| TABLE 1 Compositional Limits  
<table>
<thead>
<tr>
<th>Constituents</th>
<th>Limits (wt %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon nitride</td>
<td>97.0 min.</td>
</tr>
<tr>
<td>Free silicon</td>
<td>0.3 max.</td>
</tr>
<tr>
<td>Carbon</td>
<td>0.3 max.</td>
</tr>
<tr>
<td>Iron</td>
<td>0.1 max.</td>
</tr>
</tbody>
</table>

\(^{a}\) Other impurities or elements such as sodium, potassium, chlorine, etc. individually shall not exceed 0.02 wt % max.
8. Inspection and Verification

8.1 The intent of this section is to list potential defects and methods of inspection of finished balls. As the spectrum of applications for silicon nitride balls is very broad, this is not intended to define requirements, but to highlight these points. The type of defects, methods of inspection, and limits should be agreed upon by the customer and vendor to meet the specific requirements for a given application.

8.2 Unless otherwise specified, all dimensional and form inspections shall be performed under the following conditions:

<table>
<thead>
<tr>
<th>Properties</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density, g/cc (lb/ft³)</td>
<td>3.0 (187)</td>
<td>3.4 (212)</td>
</tr>
<tr>
<td>Elastic modulus, GPa (ksi)</td>
<td>270 (39 150)</td>
<td>330 (47 850)</td>
</tr>
<tr>
<td>Poisson’s ratio</td>
<td>0.23</td>
<td>0.29</td>
</tr>
<tr>
<td>Thermal conductivity, W/m°K (Btu/h-ft°F) – @ 20°C (room temp.)</td>
<td>20 (11.5)</td>
<td>38 (21.9)</td>
</tr>
<tr>
<td>Specific heat, J/kg°K (Btu/lbm°F)</td>
<td>650 (0.167)</td>
<td>800 (0.191)</td>
</tr>
<tr>
<td>Coefficient of thermal expansion, ×10⁶/°C (room temp. to 500°C)</td>
<td>2.3</td>
<td>3.4</td>
</tr>
<tr>
<td>Resistivity, Ohm-m</td>
<td>10¹⁰</td>
<td>10¹⁴</td>
</tr>
<tr>
<td>Compressive strength, MPa (ksi)</td>
<td>3000 (435)</td>
<td></td>
</tr>
</tbody>
</table>

^ Special material data should be obtained from individual suppliers.

<table>
<thead>
<tr>
<th>TABLE 2 Typical Mechanical Properties^A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property</td>
</tr>
<tr>
<td>-------------------------------------</td>
</tr>
<tr>
<td>Density, g/cc (lb/ft³)</td>
</tr>
<tr>
<td>Elastic modulus, GPa (ksi)</td>
</tr>
<tr>
<td>Poisson’s ratio</td>
</tr>
<tr>
<td>Thermal conductivity, W/m°K (Btu/h-ft°F) – @ 20°C (room temp.)</td>
</tr>
<tr>
<td>Specific heat, J/kg°K (Btu/lbm°F)</td>
</tr>
<tr>
<td>Coefficient of thermal expansion, ×10⁶/°C (room temp. to 500°C)</td>
</tr>
<tr>
<td>Resistivity, Ohm-m</td>
</tr>
<tr>
<td>Compressive strength, MPa (ksi)</td>
</tr>
</tbody>
</table>

^ The Flexural strength equivalents are based on Weibull volume or surface scaling using the value of m for each cell and are rounded to the nearest 5 MPa.

\[
\sigma_{3,40} = \text{denotes the flexure strength, } n = 3 \text{ or 4 point, on spans of size } L. \\
\sigma_{4,40} = 660 \text{ MPa means the four point flexure strength, on 40 mm spans is 660 MPa as per Test Method C 1161 (size B) and CEN EN 843-1.} \\
\sigma_{4,30} = 700 \text{ MPa means the four point flexure strength, on 30 mm spans is 700 MPa as per JIS R1601.}
\]

<table>
<thead>
<tr>
<th>TABLE 3 Minimum Values for Mean Flexural Strength and Weibull Modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
</tr>
<tr>
<td>Transverse-rupture strength^A</td>
</tr>
<tr>
<td>( \sigma_{3,40} )</td>
</tr>
<tr>
<td>Weibull modulus</td>
</tr>
<tr>
<td>Transverse-rupture strength^A</td>
</tr>
<tr>
<td>( \sigma_{4,40} )</td>
</tr>
</tbody>
</table>

^ The Flexural strength equivalents are based on Weibull volume or surface scaling using the value of m for each cell and are rounded to the nearest 5 MPa.

8.3 The Flexural strength equivalents are based on Weibull volume or surface scaling using the value of m for each cell and are rounded to the nearest 5 MPa.

8.4 The Flexural strength equivalents are based on Weibull volume or surface scaling using the value of m for each cell and are rounded to the nearest 5 MPa.

**TABLE 4 Minimum Values for Hardness and Toughness**

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit Load</th>
<th>Material Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness</td>
<td>HV5</td>
<td>5 kg 1500 1400 1350</td>
</tr>
<tr>
<td></td>
<td>HV10</td>
<td>10 kg 1480 1380 1325</td>
</tr>
<tr>
<td></td>
<td>HV20</td>
<td>20 kg 1460 1360 1300</td>
</tr>
<tr>
<td>Indentation Fracture Resistance, IFR (or “TP”) (Annex A1)</td>
<td>MPa/√m</td>
<td>6.0</td>
</tr>
<tr>
<td>Fracture Toughness, KIC (Test Methods C 1421 or JIS R 1607)</td>
<td>MPa/√m</td>
<td>6.0</td>
</tr>
</tbody>
</table>
8.2.1 Temperature—Room ambient 20° to 25°C (68° to 77°F).
8.2.2 Humidity—50 % relative, maximum.
8.3 Unless otherwise required, product shall be capable of passing acceptance inspection in accordance with ANSI/ASQC Z1.4 as specified in Table 8.
8.4 Certain manufacturer to manufacturer or lot to lot variation in color is acceptable. Color variation within a single ball should be investigated per 8.5.
8.5 There may exist in silicon nitride bearing balls the defects listed in Section 8.5.1, which may be inspected for using the methods in 8.5.2 as required.
8.5.1 Types of Defects:
8.5.1.1 Inclusions;

| TABLE 5 Maximum Limits for Microstructural Constituents |
|-----------------------------------|-----|-----|-----|
| Material Class | I   | II  | III |
| Porosity: Size (µm) | 10  | 10  | 25  |
| Volume Rating / ISO 4505 | 0.02 | 0.06 | 0.06 |
| Metallic Phases: Size (µm) | 10  | 10  | 25  |
| Ceramic 2nd Phases: Size (µm) | 25  | 25  | 25  |

<p>| TABLE 6 Maximum Number of Inclusions per cm² of Transverse Section |
|---------------------------------------------------------------|-----|-----|-----|</p>
<table>
<thead>
<tr>
<th>Maximum Extent in µm</th>
<th>Material Class</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>100 to &lt;200</td>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>50 to &lt;100</td>
<td></td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>25 to &lt;50</td>
<td></td>
<td>4</td>
<td>8</td>
<td>16</td>
</tr>
</tbody>
</table>

<p>| TABLE 7 Maximum Allowable Density Variation (3 × Sigma) Within a Single Lot |
|------------------------------------------------------------------------------|-----|-----|-----|</p>
<table>
<thead>
<tr>
<th>Ball Diameter in Inches (mm)</th>
<th>Density Variation (g/cm³)</th>
<th>Material Class</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/32 to &lt;15/64 (2.38 to &lt;5.95)</td>
<td>0.010</td>
<td></td>
<td>0.015</td>
<td>0.020</td>
<td></td>
</tr>
<tr>
<td>15/64 to &lt;13/32 (5.95 to 10.32)</td>
<td>0.008</td>
<td></td>
<td>0.010</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>13/32 to &lt;5/8 (10.32 to &lt;15.88)</td>
<td>0.005</td>
<td></td>
<td>0.008</td>
<td>0.012</td>
<td></td>
</tr>
<tr>
<td>5/8 to 5/16 (15.88 to 33.34)</td>
<td>0.005</td>
<td></td>
<td>0.005</td>
<td>0.010</td>
<td></td>
</tr>
</tbody>
</table>

| TABLE 8 Quality Conformance Inspections |
|----------------------------------------|-----|-----|
| Requirement | Inspection Level | AQL |
| Quality of geometry (see 8.6 for limits) | S4^ | 0.4 % |
| Quality of surface (see 8.8 for tolerances) | S4 | 0.4 % |
| Surface roughness | Use sample size shown below and accept lot if all test results are within specifications |
| Number of Balls per Lot | Sample Size |
| 0–35 000 | 5 |
| 35 001 and over | 8 |

^ Minimum sample size of 32 balls shall apply only to lots of 1200 or more pieces. For lots of less than 1200, sample size shall be set by agreement between manufacturer and customer.
8.5.1.2 Porosity;
8.5.1.3 Pits, scratches, nicks, scuffs;
8.5.1.4 Cracks or linear indications; and
8.5.1.5 Color variation.

8.5.2 Methods of Inspection:
8.5.2.1 Visual white light (unaided eye and magnification-aided eye);
8.5.2.2 Black light (unaided eye and magnification-aided eye);
8.5.2.3 Fluorescent penetrant inspection (FPI) (unaided eye and magnification-aided eye);
8.5.2.4 Ultrasonic Inspection (The following methods are currently in development and may require extensive evaluation to be applicable):
   (1) Resonant inspection (resonant ultrasound spectroscopy),
   (2) Rayleigh wave, and
   (3) Acoustic microscopy.

8.6 Dimensional and Form.
8.6.1 Tolerances by Grade for Individual Balls and Tolerances by Grade for Lots of Balls—Tests shall be in accordance with Tables 8-10. A minimum of three measurements shall be taken in random orientations on each sample ball examined.
8.6.2 Acceptable methods of determining errors in spherical forms include the following: roundness measuring equipment procedures and Vee Block examination procedure. Explanation and details of these methods shall be as indicated in ABMA STD-10. Tests shall be in accordance with Tables 8 and 9.
8.7 The nominal diameter of the balls shall be as specified in the contract or purchase order. Tolerance limits for size variations and form deviations shall be in accordance with Tables 9 and 10.
8.8 The surface roughness of the balls shall not exceed the value specified in Table 11 for the specified grade. Surface roughness shall be in accordance with ASME B 46.1.

9. Certificates of Quality and Material Certification
   (This section contains information of a general or explanatory nature which may be helpful but is not mandatory.)

| Grade (G) | Allowable Ball Diameter Variation $|V_{max}|$ | Allowable Deviation from Spherical Form $|W_{max}|$ |
|----------|----------------------------------|----------------------------------|
| 2C       | 0.05 (2)                         | 0.05 (2)                         |
| 3C       | 0.08 (3)                         | 0.08 (3)                         |
| 5C       | 0.13 (5)                         | 0.13 (5)                         |
| 10C      | 0.25 (10)                        | 0.25 (10)                        |
| 16C      | 0.40 (16)                        | 0.40 (16)                        |
| 24C      | 0.61 (24)                        | 0.61 (24)                        |
| 48C      | 1.22 (48)                        | 1.22 (48)                        |

| Grade (G) | Allowable Ball Gage Deviation (s) | Nominal Diameter Variation $|V_{max}|$ |
|-----------|-----------------------------------|------------------------|
| 2C        | ±0.51 (±20)                       | ±0.51 (±20)            |
| 3C        | ±0.51 (±20)                       | ±0.51 (±20)            |
| 5C        | ±0.76 (±30)                       | ±0.76 (±30)            |
| 10C       | ±2.54 (±100)                      | ±2.54 (+100)           |
| 16C       | ±2.54 (±100)                      | ±2.54 (+100)           |
| 24C       | ±2.54 (±100)                      | ±2.54 (+100)           |
| 48C       | N/A                               | N/A                    |

<table>
<thead>
<tr>
<th>Grade (G)</th>
<th>Maximum Surface Roughness Arithmetical Average (Ra)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2C</td>
<td>0.004 (0.15)</td>
</tr>
<tr>
<td>3C</td>
<td>0.004 (0.15)</td>
</tr>
<tr>
<td>5C</td>
<td>0.005 (0.20)</td>
</tr>
<tr>
<td>10C</td>
<td>0.006 (0.25)</td>
</tr>
<tr>
<td>16C</td>
<td>0.009 (0.35)</td>
</tr>
<tr>
<td>24C</td>
<td>0.013 (0.50)</td>
</tr>
<tr>
<td>48C</td>
<td>0.013 (0.50)</td>
</tr>
</tbody>
</table>
9.1 When specified in the contract or purchase order, certificates of quality (conformance) supplied by the manufacturer of the balls may be furnished in lieu of actual performance of such testing by the manufacturer, provided the lot identity has been maintained and can be demonstrated to the customer. The certificate may include:

9.1.1 Name of the customer,
9.1.2 Contract or purchase order number,
9.1.3 Name of the manufacturer or supplier,
9.1.4 NSN (National Stock Number) item identification number,
9.1.5 Name of the material,
9.1.6 Lot number,
9.1.7 Lot size,
9.1.8 Sample size,
9.1.9 Date of testing,
9.1.10 Test method,
9.1.11 Individual test results, and
9.1.12 Specification requirements.

9.2 When specified in the contract or purchase order, a certified report shall be available for review or when requested submitted by the manufacturer or supplier on each lot of balls. The report may contain the following:

9.2.1 Contract or purchase order number,
9.2.2 Material specification number and revision,
9.2.3 Size,
9.2.4 Quantity,
9.2.5 Batch identification code,
9.2.6 Chemical analysis of silicon nitride that meets the blank manufacturer’s specification (optional),
9.2.7 Flexural Strength (optional),
9.2.8 Materials properties as listed in Table 2 of this specification (optional),
9.2.9 Hardness,
9.2.10 Fracture toughness, and
9.2.11 Microstructure ratings.
9.2.12 A statement that this material has been processed and tested in accordance with this specification (latest revision) and/or approved material specifications.
9.2.13 Contract or purchase order requirements other than those specified within this specification will have authority over this document.

10. Packaging

10.1 For acquisition purposes, the packaging requirements shall be as specified in the contract or order.
10.2 Preservatives are not required.
10.3 Special Handling. It is recommended that for Class I applications, balls $\frac{3}{8}$ inch in diameter and greater should be packaged to prevent ball-to-ball contact.

11. Keywords

11.1 ball bearings; bearing balls; ceramic; silicon nitride; $\text{Si}_3\text{N}_4$; precision balls
A1. VICKER’S HARDNESS AND NIHARA’S TOUGHNESS MEASUREMENTS

A1.1 Measurements for hardness and toughness are made on a polished cross-section.

A1.2 Indentations for toughness measurement are made using a Vicker’s indenter under the following conditions:

<table>
<thead>
<tr>
<th>Load</th>
<th>20 kgf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dwell Time</td>
<td>30 s</td>
</tr>
</tbody>
</table>

A1.3 Hardness and toughness are calculated as follows (see Fig. A1.1):

A1.3.1 Measure both diagonals of each hardness impression as “2a” values according to orientation except when impressions are placed on separate pieces.

A1.3.2 Measure visible tip-to-tip crack lengths associated with the hardness impressions as “2c” values according to orientation except when impressions are placed on separate pieces.

A1.3.3 Calculate the mean values of $2a = (2a_1 + 2a_2)/2$ and $2c = (2c_1 + 2c_2)/2$ in micron (µm).

A1.3.4 Calculate the Vickers hardness value as follows:

$$HV = \frac{1,854,400P}{2a^2}$$

where:

- $HV$ = Vicker’s hardness number. The symbol should be written with the indentation load in kilograms denoted in parentheses (for example, HV(20) for a 20kgf load.)
- $P$ = the applied load in kilogram force (kgf).
- $a(2a/2)$ = the mean half length diagonal value in microns (µm).

A1.3.5 Calculate the indentation fracture resistance by Niihara’s method as follows:

$$IFR = 10.4 \left( E^{0.4} \right) \left( P^{0.6} \right) \left( a^{0.8} c^{1.5} \right)$$

![Fig. A1.1 Hardness and Toughness Calculation](image-url)
where:

\( IFR \) = the indentation fracture resistance in megapascals–square root meter (Mpa-m \(^{1/2}\))

\( E \) = the elastic modulus in gigapascals (Gpa).

\( P \) = the applied load in kilogram force (kgf).

\( a \) = the mean half diagonal value in microns (µm).

\( c \) = the mean half tip-to-tip crack length in microns (µm).

A1.4 Alternative formulas or calibration constants for indentation fracture resistance may be used by mutual agreement of customer and vendor.

Note A1.1—The within-lab (repeatability) consistency of results by this method may be acceptable, but the between-laboratory (reproducibility) consistency is often poor due to variations in the interpretation of the crack length arising from microscopy limitations as well as operator experience or subjectivity.
APPENDIX

(Nonmandatory Information)

X1. Examples of Typical Current Markets (Arrows Indicate Potential Overlap)

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<table>
<thead>
<tr>
<th>Class I</th>
<th>Grade 2, 3</th>
<th>Grade 5</th>
<th>Grade 10, 16</th>
<th>Grade 24, 48</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Speed Momentum Device</td>
<td>Space Mechanism</td>
<td>Lox Pump</td>
<td>Mainshaft Bearing</td>
<td>Critical Aircraft Parts</td>
</tr>
<tr>
<td>Aircraft Instrumentation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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<th>Grade 5</th>
<th>Grade 10, 16</th>
<th>Grade 24, 48</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbo Molecular Pump</td>
<td>High Precision Radial Bearing</td>
<td>Vacuum Equipment</td>
<td>Machine Tool Spindle</td>
<td>Electric Motors Med/Low Precision Radial Bearing</td>
</tr>
<tr>
<td>High Speed Instrument</td>
<td></td>
<td>Ball Screw (Non Aerospace)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dental Drills</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class III</th>
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<th>Grade 5</th>
<th>Grade 10, 16</th>
<th>Grade 24, 48</th>
</tr>
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<tbody>
<tr>
<td>Sports &amp; Recreation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food Processing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical Devices</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FIG. X1.1 Examples of Typical Current Markets (Arrows Indicate Potential Overlap)
1. Scope

1.1 This guide is a tool to aid in the choice of an oil for precision rolling element bearing applications. There are two areas where this guide should have the greatest impact: (1) when a lubricant is being chosen for a new bearing application and (2) when a lubricant for a bearing has to be replaced because the original lubricant specified for the bearing can no longer be obtained. The Report (Section 5) contains a series of tests performed by the same laboratory on a wide variety of oils commonly used in bearing applications to allow comparisons of those properties of the oil that the committee thought to be most important when making a choice of lubricant. This guide contains a listing of the properties of oils by chemical type, that is, ester, silicone, and so forth. This organization is necessary since the operational requirements in a particular bearing application may limit the choice of lubricant to a particular chemical type due to its temperature stability, viscosity index or temperature-vapor pressure characteristics, and so forth. The Report includes the results of tests on the oils included in this study. The Report recommends replacement lubricants for those oils tested that are no longer available. The Report also includes a glossary of terms used in describing/discussing the lubrication of precision and instrument bearings. The Report presents a discussion of elastohydrodynamic lubrication as applied to rolling element bearings.

1.2 Although other compendia of lubricant properties have been published, for example, the Barden Product Standard, Lubricants\(^2\) and the NASA Lubricant Handbook for the Space Industry\(^3\), none have centered their attention on lubricants commonly used in precision rolling element bearings (PREB). The PREB put a host of unique requirements upon a lubricant. The lubricant must operate at both high and low temperatures. The lubricant must provide lubrication for months, if not years, without replenishment. The lubricant must be able to support high loads but cannot be so viscous that it will interfere with the operation of the bearing at very high speeds or low temperatures, or both. The lubricant must provide boundary lubrication during low-speed or intermittent operation of the bearing. And, in many applications, its vapor pressure must be low enough under operating conditions that evaporative losses do not lead to lubricant depletion or contamination of nearby components. These and other considerations dictated the series of tests that were performed on each lubricant included in this study.

1.3 Another important consideration was encompassed in this study. Almost all of the testing was performed by the same laboratory, The Petroleum Products Research Department of the Southwest Research Institute in San Antonio, Texas, using ASTM procedures. This continuity of testing should form a solid basis for comparing the properties of the multitude of lubricants tested by avoiding some of the variability introduced when lubricants are tested by different laboratories using different or even the “same” procedures.

1.4 It should be noted that no functional tests (that is, bearing tests) were performed. The results of the four-ball wear test give some comparison, “a figure of merit,” of the lubrication properties of the oils under the condition of this test. But experience has shown that testing the lubricant in running bearings is the best means of determining lubricant performance.

2. Referenced Documents

2.1 ASTM Standards:

D 92 Test Method for Flash and Fire Points by Cleveland Open Cup\(^4\)
D 97 Test Method for Pour Point of Petroleum Products\(^4\)
D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (the Calculation of Dynamic Viscosity)\(^4\)
D 974 Standard Test Method for Acid and Base Number by Color Indicator Titration\(^5\)
D 972 Test Method for Evaporation Loss of Lubricating Greases and Oils\(^4\)
D 1331 Test Methods for Surface and Interfacial Tension of Solutions of Surface-Active Agents\(^6\)

\(^1\) This guide is under the jurisdiction of ASTM Committee F34 on Rolling Element Bearings and is the direct responsibility of Subcommittee F34.02 on Tribology.

\(^2\) “Product Standard, Lubricants,” available from The Barden Corp., Danbury, CT.


\(^4\) Annual Book of ASTM Standards, Vol 05.01.

\(^5\) Discontinued 1959; replaced by D 1663.

The relationship between kinematic viscosity and temperature can be expressed as follows:

\[ \eta = \eta_0 \exp(\alpha p) \]

where:

- \( \eta_0 \) = viscosity at a pressure of one atmosphere,
- \( \rho \) = pressure, and
- \( \alpha \) = pressure-viscosity coefficient.

A table of values of \( \alpha \) for some common classes of bearing lubricants can be found after the definition of pressure-viscosity coefficient included in this glossary.

Recent work has shown that the viscosity changes with temperature can also be modeled by an exponential relationship. Thus, viscosity at any pressure and temperature can be expressed as follows:

\[ \eta_{\gamma,p} = \eta_0 \exp(\alpha(p + \beta(1/T + 1/T_0))) \]

where:

- \( \beta \) = temperature-viscosity coefficient.

3.1.3 acid number, \( n \)—a measure of the quality of a lubricant. High acid numbers (much higher than the fresh oil) are an indication of lubricant oxidation/degradation. Oils with high acid numbers should not be used. Acid number is measured as milligrams of KOH needed to neutralize one gram of oil.

3.1.4 additive, \( n \)—any chemical compound added to a lubricant to improve or meet special needs necessary for service (formulated lubricants). The most important additives are antioxidants, rust and corrosion inhibitors, and extreme pressure (EP) and antiwear (AW) additives.

3.1.5 antioxidants (oxidation inhibitors), \( n \)—chemical compounds used to improve the oxidation stability and subsequent deterioration of lubricants.

3.1.6 boundary lubrication, \( n \)—a condition of lubrication in which the friction between two surfaces in relative motion is determined by the roughness of the surfaces and by the properties of the lubricant other than viscosity. Antiwear and extreme pressure additives reduce the wear of components operating under this regime.

3.1.7 centipoise, \( n \)—a unit of dynamic viscosity. The unit in the cgs system is one centipoise (cP). The SI unit of dynamic viscosity is 1 Pa-s and equivalent to 10^3 cP.

3.1.8 centistoke, \( n \)—a unit of kinematic viscosity. The unit in the cgs system is one centistoke (cSt). The SI unit of kinematic viscosity is 1 m^2/s and is equivalent to 10^6 cSt.

3.1.9 compatibility, \( n \)—a measure of the ability of a lubricant to be mixed with other lubricants or bearing preservatives (fluids that form films on metal surfaces to prevent corrosion during storage) to form a uniform mixture without causing any resultant reaction or precipitation of material. Compatibility is also a measure of the ability of a lubricant not to cause any detrimental effect to metal, plastic, or elastomer materials.

7 Annual Book of ASTM Standards, Vol 05.02.
3.1.9.1 Discussion—It is recommended that any preservative material be removed from bearings before lubrication.

3.1.10 contamination, n—(1) The presence of mostly solid foreign materials like sand, grinding powder, dust, and so forth, in a lubricant that might cause an increase in wear, torque, and noise and result in reduced bearing life. (2) The presence of fluids like water, solvents, and other oils that might cause accelerated oxidation, washout, rusting, or crystallization of the additives and other phenomena that reduce a bearing’s life.

3.1.11 corrosion, n—the gradual destruction of a metal surface due to chemical attack caused by polar or acidic agents like humidity (water), compounds formed by lubricant deterioration, or by contaminants from the environment.

3.1.12 corrosion inhibitors, n—corrosion inhibitors protect metal surfaces against corrosion or rust by forming a protective coating or by deactivation of corrosive compounds formed during the operation of a bearing.

3.1.13 density, n—the mass per unit volume of a substance. The cgs unit of density (ρ) is 1 g/cm³, and the SI unit of density is 1 kg/m³. Density depends on the chemical composition and in itself is no criterion of quality. It is a weak function of temperature and pressure for liquids and solids.

3.1.14 DN value, n—the product of the bearing bore diameter in millimetres multiplied by the speed in revolutions per minute (compare to nDm)value.

3.1.15 dynamic viscosity, n—another name for absolute viscosity.

3.1.16 elastohydrodynamic theory (EHD), n—See Appendix X2.

3.1.17 EP lubricants (extreme pressure lubricants), n—lubricants (oil or greases) that contain extreme pressure additives to protect the bearings against wear and welding (scoring).

3.1.18 esters, n—esters are formed from the reaction of acids and alcohols. Esters form a class of synthetic lubricants. Esters of higher alcohols with divalent fatty acids form diester lubricants while esters of polyhydric alcohols are called the polyol ester lubricants. These latter esters have higher viscosity and are more heat-resistant than diesters.

3.1.19 evaporation loss, n—lubrication fluid losses occurring at higher temperatures or under vacuum, or both, due to evaporation. This can lead to an increase in lubricant consumption and also to an alteration of the fluid properties of a lubricant (especially an increase in the viscosity of blended lubricants). The evaporation loss is expressed as a weight loss in milligrams (10⁻² kg) or wt %.

3.1.20 fire point, n—the lowest temperature at which the vapor or a lubrication fluid ignites under specified test conditions and continues to burn for at least 5 s without the benefit of an outside flame. The fire point is a temperature above the flash point. Perfluoropolyethers have no fire point.

3.1.21 flash point, n—the lowest temperature of a lubrication fluid at which the fluid gives off vapors that will ignite when a small flame is periodically passed over the liquid surface under specified test conditions. The flash and fire points provide a rough characterization of the flammable nature of lubrication fluids. Perfluoropolyethers have no flash point.

3.1.22 four-ball tester, n—a tester used to evaluate the wear behavior of lubricants under extreme pressure. Four steel balls are arranged in a pyramidal shape. During the test, the three balls comprising the base of the pyramid are stationary while the upper ball rotates. The lubricant sample is placed in the ball pot. The average wear scar (measured in millimetres) formed on the stationary balls is reported.

3.1.23 fretting corrosion, n—a special type of wear produced on materials in intimate contact that are subjected to the combined action of oscillatory motions of small amplitudes and high frequencies. Fretting corrosion appears similar to atmospheric corrosion (rust) as a reddish-brown layer on steel surfaces.

3.1.24 interfacial tension, n—when two immiscible liquids are in contact, their interface has many characteristics in common with a gas-liquid surface. This interface possesses interfacial free energy because of the unbalanced attractive forces exerted on the molecules at the interface by the molecules within the separate phases. This free energy is called the interfacial tension.

3.1.25 instrument bearings, n—all bearings whose outer diameter is 30 mm or less, as defined by The American Bearing Manufacturers Association (ABMA).

3.1.26 kinematic viscosity, n—the ratio of absolute viscosity to fluid density. This ratio arises frequently in lubrication analyses and thus kinetic viscosity has become a separate term describing the viscosity of a fluid. Many experimental measurements of viscosity of fluids result in a measure of kinematic viscosity from which absolute viscosity is calculated. See absolute viscosity. The cgs unit of kinematic viscosity is cSt, and the SI unit is m²/s. The viscosity of a PREB oil is a major factor in lubricant selection. The viscosity is directly involved in frictional, thermal, and fluid film conditions which reflect the influence of load, speed, temperature, and design characteristics of the bearing being lubricated.

3.1.27 military (MIL) specifications, n—specifications of the U.S. Armed Forces indicating the minimum mandatory requirements for an item that is to be procured. Military specifications are widely used as procurement requirements and as a quality standard.

3.1.28 mineral oil, n—oils based on petroleum stocks. These oils come in two types, naphthenic and paraffinic. The naphthenic oils contain unsaturated hydrocarbons, usually in the form of aromatic species. The paraffinic oils are primarily saturated hydrocarbons with only low levels of unsaturation.

3.1.29 nDm-value (index), n—also called speed index—a relative indicator of the lubricant stress imposed by a bearing rotating at a given speed, where n is the rotational speed of the rolling element bearing in revolutions per minute and Dm is the mean diameter in millimetres (arithmetic mean of bore diameter d and outside diameter D). The speed index is multiplied by a factor k with depending on the roller element bearing type:

\[ k_1 = 1 \text{ for deep groove ball bearings, angular contact ball bearings, self-aligning ball bearings, radially loaded cylindrical roller bearings, and thrust ball bearings,} \]
\[ k_2 = 2 \text{ for spherical roller bearings, taper roller bearings, and needle roller bearings, and} \]
\[ k_3 = 3 \text{ for axially loaded cylindrical roller bearings and full complement roller bearings.} \]
The factor $k$, takes into account the various rates of sliding friction that usually occurs during the operation of a rolling element bearing. The $nD_m$-value is an aid in choosing a suitable lubricant viscosity for a given bearing speed and is particularly applicable to grease-lubricated bearings.

3.1.30 neutralization number, $n$—a measure of the acidity or alkalinity of a lubricating fluid. The test determines the quantity of base (milligrams of potassium hydroxide) or acid (also expressed as milligrams of potassium hydroxide) needed to neutralize the acidic or alkaline compounds present in a lubricating fluid. Actually, the neutralization number is not one number but several numbers: strong acid number, total acid number, strong base number, and total base number. The neutralization number is used for quality control, and to determine changes that occur in a lubricant in service.

3.1.31 oxidation stability, $n$—the stability of a lubricant in the presence of air or oxygen is an important chemical property. Oxidation stability has a strong influence on numerous physical properties of a lubricant. These properties include the change of viscosity under static conditions for long periods of time (storage) or when exposed to temperatures high above room temperature, or both. The slow chemical reaction of fluid (base oil) and oxygen (air) is called oxidation. Inhibitors (see antioxidants) are used to improve the oxidation stability of the lubricants. Synthetic fluids, especially perfluoropolyethers and silicones, are much more resistant to oxidation than mineral oils.

3.1.32 precision bearings, $n$—regardless of size, the class of bearings used in instrument types of applications and with similar tolerances as instrument bearings. Bearings usually used in these applications are of high quality and are not put under high stress, thus they usually do not fail under fatigue.

3.1.33 perfluoropolyethers (PFPE or PFAE), $n$—fully fluorinated long-chain aliphatic ethers. The perfluoropolyethers show some extraordinary properties like chemical inertness, nonflammability, high thermal and oxidative resistance, very good viscosity-temperature characteristics, and compatibility with a wide range of materials, including metals and plastics. The perfluoropolyethers, however, are not suitable for use with aluminum, magnesium, and titanium alloys. The perfluoropolyethers are not compatible with other types of synthetic fluids and mineral oils and cannot dissolve common lubricant additives.

3.1.34 pH value, $n$—a scale for measuring the acidity or alkalinity of a product. Zero pH is very acid, 7 is neutral, and 14 is very alkaline.

### TABLE 1 Pressure-Viscosity Coefficients for the Lubricant Classes Covered in This Guide

<table>
<thead>
<tr>
<th>Oil Type</th>
<th>$\alpha$ (GPa$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral oil (paraffinic-napthenic)</td>
<td>21</td>
</tr>
<tr>
<td>Mineral oil (napthenic-aromatic)</td>
<td>30</td>
</tr>
<tr>
<td>Polyalpholefin</td>
<td>18</td>
</tr>
<tr>
<td>Diester-(2-ethylhexyladipate)</td>
<td>7.6</td>
</tr>
<tr>
<td>Polyolester (pentaerythritolvalerate)</td>
<td>7.5</td>
</tr>
<tr>
<td>Polydimethylsilicone (1000 mm$^2$/s at 40°C)</td>
<td>2.3</td>
</tr>
<tr>
<td>PFPE-linear</td>
<td>4–12</td>
</tr>
<tr>
<td>PFPE-branched</td>
<td>26–36</td>
</tr>
</tbody>
</table>

$^1 \text{atm} = 0.001013 \text{ GPa}$.

3.1.35 poise (P), $n$—See centipoise (cP).

3.1.36 pour point, $n$—(of a lubricating fluid)—the lowest temperature at which the lubricating fluid will pour, or flow.

3.1.37 pressure-viscosity coefficient, $n$—the dynamic viscosity of a fluid increases with increasing pressure. The dependence of viscosity (absolute), $\eta$, on pressure, $p$, can be expressed by the equation:

$$\eta = \eta_0 \exp (\alpha p)$$

where:

$\eta = \text{absolute viscosity at pressure, } p,$

$\eta_0 = \text{absolute viscosity at one atmosphere, and}$

$\alpha = \text{the pressure-viscosity coefficient.}$

The pressure-viscosity coefficient is very small and varies with the chemical composition of the fluid. Some values of $\alpha$ for the classes of lubricants discussed in the Report section are given in Table 1.9

One limitation of the use of $\eta_0$ and the corresponding equation is that the measurements of $\eta_0$ are made under static conditions where the pressure is held constant while the viscosity attains a steady-state value. In actual bearing operations, the lubricant may see high pressure in the contact zone for only a few milliseconds and the viscosity changes due to this high pressure may not reach steady-state values.

3.1.38 rated viscosity, $(\nu_1), n$—the kinematic viscosity attributed to a defined lubricating condition of a rolling element bearing. The rated viscosity is a function of the speed and can be determined by the mean bearing diameter in millimetres ($10^{-3}$ m) and the rotational speed (rpm). More details can be found in Appendix X2.

3.1.39 repeatability, $n$—a criterion for judging the acceptability of test results. Repeatability is the difference between successive test results obtained by the same operator with the same apparatus under constant operating conditions on identical test material. Repeatability is usually reported as a range of values that would, in the normal and correct operation of the test method, encompass two standard deviations from the median value of the test.

3.1.40 reproducibility, $n$—a criterion for judging the acceptability of test results. Reproducibility is the difference between two single and independent results, obtained by different operators working with identical test material. This difference, in the long run and under normal and correct operation of the test method, would not exceed a specified value.

3.1.41 saponification number, $n$—a measure of the amount of constituents of a lubrication fluid that will easily saponify under test conditions. The saponification number is expressed in milligrams of potassium hydroxide that are required to neutralize the free and bonded acids contained in one gram of lubricating fluid. The saponification number is a measure of fatty acids compounded in an oil and a measure of the state of oil deterioration.

3.1.42 saponify, $v$—to hydrolyze an ester and to convert the free acid into soap.

3.1.43 seal compatibility, $n$—the extent of the reaction of sealing materials with lubricating oils, greases, and other
3.1.44 **setting point**, \( n \)—of a lubricating fluid—the temperature at which the fluid ceases to flow when cooled under specified conditions. The low-temperature behavior of the fluid slightly above the setting point may be unsatisfactory and, therefore, this behavior should be determined by measuring the low-temperature kinematic or absolute viscosity.

3.1.45 **shelf life**, \( n \)—the expression shelf life of a lubricant is not exactly specified. Two versions of the definition exist:

1. **shelf life**—the ability of a lubricated part to function even after long-term storage. This definition is very critical because it includes not only the aging properties of the lubricant used but also the loss of lubricant due to evaporation and creeping.

2. **shelf life**—the storage stability of the bulk lubricant in its original container. Stability is defined here as no change in the physical or chemical properties of the lubricant.

3.1.46 **silicone oils**, \( n \)—synthetic fluids composed of organic esters of long chain complex silicic acids. Silicone oils have better physical properties than mineral oils. However, silicone oils have poorer lubrication properties, lower load-carrying capacity, and a strong tendency to spread on surfaces (see **surface tension**). To prevent this spreading the use of barrier films is necessary.

3.1.47 **stability**, \( n \)—the resistance of a lubricant to a change in its properties after being stored for a defined period of time. The methods to test a lubricant for stability are defined in individual military or commercial specifications.

3.1.48 **surface energy/surface tension**, \( n \)—a fundamental property of liquids is the existence of a free energy at the surface. A consequence of this free energy is the property that a liquid spontaneously contracts to the smallest possible area. For example, liquid droplets assume a spherical shape if no outside forces are acting on the droplet. To deform the droplet from its spherical shape, a definite amount of work must be done. This work (or energy expended) when normalized per unit area is called surface tension and has the unit mN/m (formally dyne/cm). Surface tension is dependent upon temperature but not upon pressure. The surface tension is a measure for the wetting of a bearing surface and for the creeping (spreading) property of a lubricant. Fluids with low surface tensions like dimethylsilicones show improved wetting but increased creeping (migration) tendency.

3.1.49 **swelling properties**, \( n \)—the swelling of natural rubber and elastomers under the influence of lubricants.

3.1.50 **synthetic fluids**, \( n \)—lubricating fluids produced by chemical synthesis. The synthetic route to lubricants allows the manufacturer to introduce those chemical structures into the lubricant molecule that will impart specific properties into the resultant fluid such as very low pour point, good viscosity-temperature relationship, low evaporation loss, long lubricating lifetime, and so forth.

3.1.51 **viscosity**, \( n \)—See **absolute viscosity**.

3.1.52 **viscosity index** (VI), \( n \)—indicates the range of change in viscosity of a lubricating fluid within a given temperature range. With an increase in the viscosity index, the fluid becomes less sensitive to temperature, that is, a low-viscosity index signifies a relatively large change, whereas a high-viscosity index relates to a relatively small change in viscosity with temperature.

3.1.53 **wear**, \( n \)—the attrition or rubbing away of the surface of material as a result of mechanical action.

4. **Significance and Use**

4.1 The purpose of this guide is to report on the testing of, to discuss and compare the properties of, and to provide guidelines for the choice of lubricants for precision rolling element bearings (PREB). The PREB are, for the purposes of this guide, meant to include bearings of ABEC 5 quality and above. This guide limits its scope to oils used in PREB and is to be followed by a similar document to encompass greases used in PREB.

4.2 The number of lubricants, both oils and greases, used in PREB increased dramatically from the early 1940s to the mid 1990s. In the beginning of this period, petroleum products were the only widely available base stocks. Later, synthetic lubricants became available including synthetic hydrocarbons, esters, silicones, and fluorinated materials, including perfluorinated ethers and the fluoro-silicones. This broad spectrum of lubricant choices has led to the use of a large number of different lubricants in PREB applications. The U.S. Department of Defense, as a user of many PREB, has seen a significant increase in the logistics effort required to support the procurement and distribution of these items. In addition, as time has passed some of the lubricants used in certain PREB are no longer available. The SRG Series, LSO-26, and Teresso V-78 are examples of such lubricants. This implies that replacement lubricants must be found as, in this era of extending the lifetime of DoD assets, stockpiles of replacement parts become depleted.

4.3 One of the primary goals of this study was to take a broad spectrum of the lubricants used in PREB and do a comprehensive series of tests on them in order that their properties could be compared and, if necessary, potential replacement lubricants identified. This study is also meant to be a design guide for choosing lubricants for PREB applications. This guide represents a collective effort of many members of this community who span the spectrum from bearing manufacturers, original equipment manufacturers (OEMs), lubricant manufacturers and suppliers, procurement specialists, and quality assurance representatives (QARs) from DoD and end users both inside and outside DoD.

5. **Report**

5.1 Tables 2-6 give the test results of the 44 PREB oils tested. Each oil was tested for kinematic viscosity, pour point, flash point, evaporation loss, surface tension, four-ball wear, and acid number. In addition, a viscosity index was calculated for each of the oils tested by using the kinematic viscosities at 40°C and 100°C in cSt and using the following formula:

\[
VI = (L - U) / (L - H) \times 100
\]
where:

- \( VI \) = viscosity index,
- \( U \) = viscosity at 40°C of the oil tested, and
- \( H \) and \( L \) = the viscosities of viscosity index reference oils (VI = 100 and VI = 0, respectively) at 40°C in accordance with Practice D 2270.

The preceding method for obtaining VI is not appropriate if it results in a VI > 100. For VI values above 100, an empirical fit was developed to yield the following equation:

\[
VI = (10^N - 1) / 7.15 \times 10^{-3} + 100
\]

where:

\[
N = (\log H - \log U) / \log Y, \text{ where } Y \text{ is the viscosity of the oil of interest, cSt at 100°C}
\]

All of the testing of the oils was done by the Petroleum Products Research Department of the Southwest Research Institute in San Antonio, Texas using ASTM procedures.

### 6. Recommendations and Conclusions

6.1 The 44 oils tested were divided into 5 different chemical classifications (mineral oils, polyalphaolefins, esters, silicones, and perfluorinated aliphatic ethers). It is concluded that many of the oils within a given classification (and between classifications) have similar physical properties, and comparison of these properties can be a useful first step in selecting oil candidates for a given application. The data may also be useful when selecting alternate lubricants to replace one that is no longer available or to reduce the number of oils kept in inventory.

6.1.1 By chemical classification the committee recommends the following:

6.1.1.1 *Mineral Oils*—The use of mineral oils is, in general, not recommended. These oils can vary from lot to lot depending upon the source of the crude oil used as feedstock and upon the exact chemical and physical processes used to refine the feedstock. The main advantage of mineral oils over synthetic hydrocarbon oils is cost. In most PREB applications, the cost of using either type of lubricant is usually a very small part of the overall cost of the bearing. Therefore, in most PREB applications, the differential cost of using a mineral oil versus a PAO (synthetic hydrocarbon) should not be a determining factor in the choice of oil.
6.1.1.2 Polyalphaolefins—The synthetic hydrocarbon base stocks (PAOs) are very similar in chemical structure to paraffinic mineral oils yet have the advantage of being synthetically produced. Synthetically producing an oil gives the manufacturer considerably more control over its chemical composition and thus controls the variability from lot to lot. The use of PAOs is recommended for many PREB applications. The PAOs exhibit many of the physical properties that are required for the lubrication of PREB and have a history of being used successfully in PREB. If the use of a PAO is deemed appropriate for a PREB application, the committee recommends that the initial choice of a lubricant be one that meets the MIL-DTL-53131 specification. This specification, which encompasses five viscosity grades, was written specially to provide an oil with the physical and chemical properties considered appropriate for most PREB applications. If a very low vapor pressure is a requirement for a PREB application, another new class of synthetic hydrocarbons, the alkylated cyclopentanes, may prove to be an alternative choice. Unfortunately, these fluids appeared after the conclusion of the testing phase of this guide and are not included in the oil database.

6.1.1.3 Ester Oils—This class of oils can be used in PREB applications. The main advantage is that ester oils have excellent lubricity and compatibility with a wide variety of additives. Ester oils also have somewhat better low-temperature behavior and are a little more resistant to thermo-oxidative degradation at temperatures above about 150°C than PAO oils. If these two advantages are not significant for a PREB application, a synthetic hydrocarbon may be substituted for an ester oil.

6.1.1.4 Silicone Oils—The use of silicone oils is not recommended in PREB unless the very high-viscosity index or the damping properties of these oils are critical to the PREB application. The very poor lubricity of silicone oils, tendency to creep, the fact that they can, under certain conditions, form glass-like, fairly hard deposits and, the difficulty in cleaning silicone oils from lubricated parts may be issues when considering silicone oils as a PREB lubricant.

**TABLE 4 Properties of PREB Ester-Based Oils**

<table>
<thead>
<tr>
<th>Esters</th>
<th>Kinematic Viscosity, mm²/s</th>
<th>Properties</th>
<th>Density (0.92 – 1.01 g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40°C</td>
<td>100°C</td>
<td>Low Temperature</td>
</tr>
<tr>
<td></td>
<td>Viscosity Index (VI)</td>
<td>Pour Point [°C]</td>
<td>Flash Point [°C]</td>
</tr>
<tr>
<td>Tenneco L 401D</td>
<td>12.54 5.00 10 949 (-54°C)</td>
<td>174 185 0.84 25.98</td>
<td>0.9 0.22</td>
</tr>
<tr>
<td>Allied Signal Pioneer P10¹</td>
<td>13.08 4.38 10 604 (-54°C)</td>
<td>155 182 1.77 29.20</td>
<td>1.0 0.34</td>
</tr>
<tr>
<td>Bracoyo 885</td>
<td>13.66 3.59 7269 (-52°C)</td>
<td>157 227 0.50 31.45</td>
<td>0.9 0.17</td>
</tr>
<tr>
<td>Castrol 399</td>
<td>11.88 3.07 7269 (-54°C)</td>
<td>122 218 0.53 28.67</td>
<td>0.8 0.26</td>
</tr>
<tr>
<td>Castrol 5050</td>
<td>24.86 4.95 12 312 (-42°C)</td>
<td>126 264 0.81 28.67</td>
<td>0.7 0.02</td>
</tr>
<tr>
<td>Grignard TN-3</td>
<td>13.85 3.51 4637 (-54°C)</td>
<td>140 243 0.44 28.10</td>
<td>1.1 0.65</td>
</tr>
<tr>
<td>Kluber Isoflex PDP 38</td>
<td>12.11 3.30 8755 (-54°C)</td>
<td>154 213 3.46 27.76</td>
<td>0.9 0.22</td>
</tr>
<tr>
<td>Kluber Isoflex Alltime 28K</td>
<td>24.31 5.01 4388 (-47°C)</td>
<td>136 218 1.16 26.14</td>
<td>0.5 0.39</td>
</tr>
<tr>
<td>Nye NPE-UC 4</td>
<td>17.42 3.98 14 652 (-49°C)</td>
<td>127 245 1.99 29.63</td>
<td>0.7 0.18</td>
</tr>
<tr>
<td>Nye NPE-UC 7</td>
<td>36.01 6.60 21 878 (-42°C)</td>
<td>140 273 1.96 28.89</td>
<td>0.8 0.28</td>
</tr>
<tr>
<td>Nye NPE-UC 9</td>
<td>50.95 8.40 13 169 (-37°C)</td>
<td>140 286 0.47 29.34</td>
<td>0.6 0.01</td>
</tr>
<tr>
<td>Nye Synthetic Oil 500 R</td>
<td>48.69 8.65 40 492 (-39°C)</td>
<td>157 266 1.97 28.64</td>
<td>0.3 0.42</td>
</tr>
<tr>
<td>Windsor L 245 X</td>
<td>12.66 3.42 8893 (-54°C)</td>
<td>158 185 0.45 28.84</td>
<td>1.0 0.00</td>
</tr>
</tbody>
</table>

¹ See Table X3.1 for manufacturer information.
² No longer available.

**TABLE 5 Properties of PREB Silicone-Based Oils**

<table>
<thead>
<tr>
<th>Silicone Oils</th>
<th>Kinematic Viscosity, mm²/s</th>
<th>Properties</th>
<th>Density (0.96 – 1.11 g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40°C</td>
<td>100°C</td>
<td>Low Temperature</td>
</tr>
<tr>
<td></td>
<td>Viscosity Index (VI)</td>
<td>Pour Point [°C]</td>
<td>Flash Point [°C]</td>
</tr>
<tr>
<td>Polydimethyl silicones:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dow Corning</td>
<td>37.31 15.67 395 (-54°C)</td>
<td>432 696 1.08 18.81</td>
<td>2.34 0.01</td>
</tr>
<tr>
<td>510 fluid. 50 cSt</td>
<td>37.24 14.81 993 (-54°C)</td>
<td>412 &lt;-75 275 0.28 23.44</td>
<td>2.18 0.11</td>
</tr>
<tr>
<td>Novaguard</td>
<td>49.00 15.50 2500 (-54°C)</td>
<td>332 &lt;-75 288 0.64 19.34</td>
<td>1.1 0.10</td>
</tr>
<tr>
<td>Versilube F 50</td>
<td>208.11 31.01 6000 (0°C)</td>
<td>193 &lt;5 -15 300 0.06 29.93</td>
<td>5.03 0.05</td>
</tr>
<tr>
<td>Polymethylphenyl silicones:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dow Corning</td>
<td>710 fluid</td>
<td>208.11</td>
<td>31.01 6000 (0°C) 193 &lt;5 -15 300 0.06 29.93</td>
</tr>
<tr>
<td>Fluorosilicones.¹</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dow Corning</td>
<td>Q5-0161</td>
<td>71.17</td>
<td>20.65 13 988 (-54°C) 314 &lt;-75 216 0.41 26.31</td>
</tr>
<tr>
<td>FS 1265, 300cSt</td>
<td>161.65 28.46 939 (-30°C)</td>
<td>216 &lt;-43 260 2.76 20.50</td>
<td>0.35 0.12</td>
</tr>
</tbody>
</table>

¹ See Table X3.1 for manufacturer information.
² The density of the fluorosilicones is 1.25 g/cm³.
6.1.1.5 Perfluoropolyethers (PFPE)—The use of PFPE oils in PREB is not recommended unless their very high-viscosity index, their very high thermo-oxidative stability, or their very low-vapor pressure are overriding concerns in the PREB application. The tendency to creep, the fact that the PFPE cannot be formulated with most of the effective lubricant additives, the PFPE poor boundary lubrication properties, and relatively high cost may be issues when considering PFPE as a PREB lubricant.

7. Keywords

7.1 ball bearings; ester oil; instrument and precision bearing lubricants; mineral oil; perfluoropolyether oil; polyalphaolefins; silicon oil

7.1.5 Perfluoropolyethers (PFPE)—The use of PFPE oils in PREB is not recommended unless their very high-viscosity index, their very high thermo-oxidative stability, or their very low-vapor pressure are overriding concerns in the PREB application. The tendency to creep, the fact that the PFPE cannot be formulated with most of the effective lubricant additives, the PFPE poor boundary lubrication properties, and relatively high cost may be issues when considering PFPE as a PREB lubricant.

ANNEX

(Mandatory Information)

A1. PROPERTIES OF OILS—BASE STOCKS

A1.1 In the selection of a proper lubricating oil for a given operating condition it is necessary to know the characteristics of the base stock. Therefore, the main properties of the base stocks that are part of this guide will be discussed. It is also recommended that a review of the material safety data sheet be included in the selection process of a lubricant. This will allow an assessment of the health/handling risks associated with a particular oil.

A1.2 Mineral Oils

A1.2.1 Use—Multipurpose lubricant for large rolling element bearings, engines, gears, and so forth. These oils can be blended with polyalphaolefins (PAOs) or esters to improve their lubricity and temperature-viscosity characteristics.

A1.2.2 Structure—Due to the origin and the treatment of the base stocks, the formulated oils exhibit different chemical compositions and variations in their properties.

A1.2.3 Advantages:
A1.2.3.1 Available in a wide range of viscosity grades.
A1.2.3.2 Excellent lubricity.
A1.2.3.3 Additives can improve performance (antioxidants, corrosion protection, antiwear and EP properties, and so forth).

A1.2.4 Disadvantages:
A1.2.4.1 These oils age and oxidize at temperatures above approximately 100°C and form resins, carbonaceous deposits, and so forth.
A1.2.4.2 Viscosity index is lower than that of most synthetic fluids (that is, viscosity changes more rapidly with temperature).
A1.2.4.3 Oils used in instrument bearings have a relatively high vapor pressure.
A1.2.4.4 Not miscible with silicones and perfluoropolyethers.
A1.2.4.5 Usually are not preferred in applications where temperatures lie outside of the range from -30 to 100°C.10

A1.2.4.6 This temperature limit is only a general guideline. Individual mineral oils may perform at temperature limits significantly different from this.

A1.2.5 Most sealing materials are compatible (little swelling or shrinking).
A1.2.5.1 Most paints are compatible.
A1.2.5.2 Not miscible with silicones and perfluoropolyethers.
A1.2.5.3 Not preferred in applications where temperatures lie outside of the range from -30 to 100°C.

TABLE 6 Properties of PREB Perfluoropolyether-Based Oils

<table>
<thead>
<tr>
<th>Perfluoropolyethers&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Kinematic Viscosity, mm²/s</th>
<th>Density (1.87 – 1.90 g/cm³)</th>
<th>Viscosity Index (VI)</th>
<th>Pour Point [°C]</th>
<th>Flash Point [°C]</th>
<th>Evaporation Loss [% wt]</th>
<th>Surface Tension (22°C) [dyn/cm]</th>
<th>4-Ball Wear [MN/m] or [mm]</th>
<th>Acid Number [mg KOH/g]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear chain:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brayco 814</td>
<td>18.11</td>
<td>6.04</td>
<td>1200 (-54°C)</td>
<td>329</td>
<td>&lt;=-75</td>
<td>ND&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.45</td>
<td>23.0</td>
<td>0.58</td>
</tr>
<tr>
<td>Brayco 815 Z</td>
<td>145.00</td>
<td>45.00</td>
<td>1200 (-54°C)</td>
<td>347</td>
<td>&lt;=-75</td>
<td>ND&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.02</td>
<td>21.0</td>
<td>1.20</td>
</tr>
<tr>
<td>KluBer (fluid)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barrierta FOY 150</td>
<td>154.20</td>
<td>47.26</td>
<td>4000 (-40°C)</td>
<td>346</td>
<td>&lt;=-66</td>
<td>ND&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.04</td>
<td>21.9</td>
<td>1.00</td>
</tr>
<tr>
<td>Branched chain:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dupont Krytox 143 AC</td>
<td>226.18</td>
<td>23.36</td>
<td>21 000 (-15°C)</td>
<td>128</td>
<td>-36</td>
<td>ND&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.27</td>
<td>21.5</td>
<td>1.46</td>
</tr>
<tr>
<td>KluBer (fluid)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barrierta 0</td>
<td>27.72</td>
<td>4.74</td>
<td>9800 (-35°C)</td>
<td>87.4</td>
<td>-48</td>
<td>ND&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.00</td>
<td>21.9</td>
<td>0.43</td>
</tr>
<tr>
<td>Barrierta EL</td>
<td>97.90</td>
<td>12.27</td>
<td>48 000 (-30°C)</td>
<td>118</td>
<td>-45</td>
<td>ND&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.78</td>
<td>21.9</td>
<td>0.51</td>
</tr>
<tr>
<td>Barrierta I EL</td>
<td>197.28</td>
<td>21.90</td>
<td>60 000 (-25°C)</td>
<td>134</td>
<td>-39</td>
<td>ND&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.34</td>
<td>21.9</td>
<td>0.70</td>
</tr>
<tr>
<td>Barrierta I S</td>
<td>392.41</td>
<td>38.42</td>
<td>72 000 (-20°C)</td>
<td>145</td>
<td>-34</td>
<td>ND&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.10</td>
<td>21.9</td>
<td>1.31</td>
</tr>
</tbody>
</table>

<sup>a</sup> See Table X3.1 for manufacturer information.

<sup>b</sup> Not determined.
A1.3 Polyalphaolefins (PAOs)

A1.3.1 Use—The PAOs are used to lubricate rolling element bearings in guidance systems, gimbals, gyros, and so forth. The PAOs are used as a base oil for PREB lubricants, especially for wide temperature and high-speed applications.

A1.3.2 Structure—PAOs, that is, synthetic paraffinic fluids, are primarily straight chain, saturated hydrocarbons. The PAOs differ in chain length, the degree of branching and in the position of the branches. The absence of unsaturation increases their thermo-oxidative stability.

A1.3.3 Advantages:
- A1.3.3.1 Available in a wide range of viscosity grades.
- A1.3.3.2 High thermal and oxidative stability.
- A1.3.3.3 Low evaporation rates.
- A1.3.3.4 Excellent viscosity-temperature behavior.
- A1.3.3.5 Resistant against hydrolysis.
- A1.3.3.6 High viscosity grades are compatible with most sealing materials and paints.
- A1.3.3.7 Fully miscible with mineral oils and esters.
- A1.3.3.8 A full range of additives are available.
- A1.3.4 Disadvantages:
- A1.3.4.1 Low viscosity grades may shrink/swell sealing materials.
- A1.3.4.2 Not miscible with silicones and perfluoropolyethers.
- A1.3.4.3 More costly than mineral oils.

A1.4 Esters

A1.4.1 Use—These fluids are used for lubrication of PREB. They serve as a base oil for low-temperature and high-speed lubricants.

A1.4.2 Structure—Diesters are esters usually based on lower molecular weight branched-chain alcohols reacted with C₄ to C₁₀ aliphatic acids (usually forming azelates and sebacates). The polyolesters are synthesized from the alcohols trimethyl propane (TMP) or pentaerythritol and C₄ to C₈ acids.

A1.4.3 Advantages:
- A1.4.3.1 Excellent low-temperature characteristics.
- A1.4.3.2 Suitable for high-temperature applications up to 150°C.
- A1.4.3.3 Excellent lubricity.
- A1.4.3.4 Able to dissolve a wide concentration range of most additives.
- A1.4.3.5 Low evaporation rates for some diesters and most polyesters.
- A1.4.3.6 High thermal and oxidative stability.
- A1.4.3.7 Miscible with mineral oils, polyalphaolefins, and polyphenylmethysilicones.

A1.4.4 Disadvantages:
- A1.4.4.1 Only available in low to medium viscosity grades.
- A1.4.4.2 Incompatible with some sealing materials such as BUNA-N, NBR, and EPDM elastomers.
- A1.4.4.3 May interact with paint and other polymeric coatings.
- A1.4.4.4 Can hydrolyze under humid conditions that may cause corrosion.
- A1.4.4.5 Not miscible with polydimethylsilicones and perfluoropolyethers.
- A1.4.4.6 More costly than mineral oils.

A1.5 Silicones

A1.5.1 Use—Silicones are used as lubricants for extremely low temperature (down to -75°C) applications. They may also be used for high temperature (up to 220°C) applications under light loads.

A1.5.2 Structure—There are three classes:
- A1.5.2.1 Polydimethylsilicones have a linear chain structure with methyl groups.
- A1.5.2.2 Polyphenylmethylsilicones (siloxanes) have a linear chain structure with methyl and phenyl groups. Siloxanes with a high ratio of phenyl to methyl groups show a decrease in evaporation and low temperature properties over that exhibited by the polydimethylsilicones. Siloxanes also show an improvement in thermal and oxidative stability and in surface tension properties.
- A1.5.2.3 Fluorinated silicones have a branched structure based on perfluoroalkyl groups. Fluids having a branched chain structure exhibit better load-carrying capacity.

A1.5.3 Advantages:
- A1.5.3.1 Available in a wide viscosity range.
- A1.5.3.2 Polydimethylsilicones along with the linear perfluoropolyethers exhibit the best viscosity-temperature behavior of all lubricating oils.
- A1.5.3.3 Excellent low temperature properties.
- A1.5.3.4 Low evaporation rates.
- A1.5.3.5 Compatible with almost all plastics and sealing materials with the exception of those based on silicones.
- A1.5.3.6 Good damping properties.
- A1.5.4 Disadvantages:
- A1.5.4.1 Low surface tension (high tendency to spread and creep with the exception of the polyphenylmethysilicones).
- A1.5.4.2 Very poor lubricity.
- A1.5.4.3 Can polymerize to glassy materials at elevated temperatures and under medium to heavy loads.
- A1.5.4.4 Not miscible with mineral oils, polyalphaolefins, esters, and perfluoropolyethers.
- A1.5.4.5 Difficult to remove by solvents.
- A1.5.4.6 Can decompose in electrical arcs (electrical contacts) forming abrasive deposits.

A1.6 Perfluoropolyethers (Perfluorinated Aliphatic Ethers) (acronyms—PFPE, PFAE)

A1.6.1 Use—These fluids are used as the base oil for high-temperature and oxygen-resistant lubricants. Both linear and branched-chain perfluoropolyethers are available. The linear PFPEs are primarily used for vacuum and space applications or where use at very low temperatures is required.

A1.6.2 Structure—These materials are long chain polyethers containing fully fluorinated alkyl groups. The fluorocarbon subunits may have a linear or branched-chain structure or a mixture of these two subunits.

A1.6.3 Advantages:
- A1.6.3.1 Extraordinary high thermal and oxidative resistance.
- A1.6.3.2 High resistance to chemical attack.
- A1.6.3.3 Wide operating temperature range.
A1.6.3.4 Very low vapor pressure and evaporation rate; PFPEs with a linear structure have a significantly lower vapor pressures than their branched-counterparts.
A1.6.3.5 Medium to excellent viscosity-temperature behavior (linear structure–excellent, branched structure–medium).
A1.6.3.6 Compatible with sealing materials, plastics, and paints.
A1.6.4 Disadvantages:
A1.6.4.1 Low surface tension (spreading, creeping).
A1.6.4.2 Common lubricant additives are not soluble in these materials.
A1.6.4.3 Poor corrosion protection.
A1.6.4.4 Not suitable for aluminum, magnesium, and titanium alloys.
A1.6.4.5 Not miscible with other base stocks: mineral oils, esters, PAOs, silicones, and so forth.
A1.6.4.6 High density (approximately 1.9 g/mL).
A1.6.4.7 Poor boundary lubrication properties.
A1.6.4.8 May cause insulating films at electrical contacts.
A1.6.4.9 Can deposit monolayer films of PFPE species that are difficult to remove by solvents. The monolayer films will make bearing surfaces unwettable.
A1.6.4.10 High cost, especially for linear PFPEs.

APPENDIXES
(Nonmandatory Information)

X1. RECOMMENDED REPLACEMENT LUBRICANTS FOR OUTDATED FLUIDS

<table>
<thead>
<tr>
<th>Outdated Oil</th>
<th>Recommended Replacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kendall SRG-40</td>
<td>MIL-DTL-53131 Grade 6</td>
</tr>
<tr>
<td>Kendall SRG-60</td>
<td>MIL-DTL-53131 Grade 9 or 14</td>
</tr>
<tr>
<td>Kendall SRG-80</td>
<td>MIL-DTL-53131 Grade 14</td>
</tr>
<tr>
<td>Teresseo V-78</td>
<td>MIL-DTL-53131 Grade 14</td>
</tr>
<tr>
<td>Bendix Pioneer P-10</td>
<td>MIL-L-6085</td>
</tr>
</tbody>
</table>

Note: X1.1—The committee realizes that oil selection or replacement based on the data and properties information presented in this guide alone could be very risky due to the many other factors unique to any specific application (compatibility and environmental issues, system operating parameters and requirements, life issues, and so forth). Therefore, it is the committee’s overall recommendation that this guide be used for “first cut” lubricant selections only. It is strongly recommended that each user fully evaluate lubricants for acceptability in their specific application and under conditions duplicating the system environment as closely as possible. Lubricant selection should be made only after successful performance in system tests has been demonstrated.

X2. DISCUSSION OF ELASTOHYDRODYNAMIC LUBRICATION

X2.1 The life of miniature and small-size rolling element bearings is controlled by wear processes. In addition to the wear processes, larger bearings sizes may also undergo fatigue processes. To prevent or at least to reduce wear and damage to the surfaces of the bearing elements and to prolong the lifetime of rolling element bearings, a separation of the mating surfaces by means of a lubricating film of a sufficient thickness is necessary.

X2.2 The EHD theory is concerned with the thickness of the lubricating film built up between the rolling elements of a rolling element bearing (it can also be used for highly loaded gears and cams). The thickness of the lubricating film depends on the elastic deformation (Fig. X2.1) of the rolling element materials (steel or hybrid bearing), the bearing size, speed, the lubricant’s operating viscosity, and on the lubricant quantity.

X2.3 The lubricant quantity rules the supply to the inlet zone of the contact and therefore has a direct effect on the film formation in the EHD contact zone. Depending on the lubricant supply and the resulting film thickness, EHD can be classified into three regimes: (1) parched EHD regime, (2) starved EHD regime, and (3) fully flooded EHD regime. The EHD theory was developed for oil lubrication but the principles can also be applied to grease lubrication.

X2.4 The lubricating film thickness between surfaces in rolling contacts according to the EHD theory can be calculated using Eq X2.1. The necessary parameters are shown in Fig. X2.2 for a line contact.

\[ h_s = \frac{0.1 \alpha^{0.6} (\eta \nu)^{0.7} (Q/\pi)^{0.63} (1 - \mu)^{0.63}}{(1/r_1 + 1/r_2)^{0.44} E} \]  
(X2.1)
where:

$h_o$ = minimum lubricating film thickness that will prevent roller/raceway contact (fully flooded EHD), $\mu$m

$\alpha$ = pressure-viscosity coefficient, $\alpha$

$\eta$ = absolute (dynamic) viscosity, mPa-s,

$\nu$ = $(\nu_1 + \nu_2)/2$ speeds, m/s,

$r_1$ = roller radius, m,

$r_2$ = inner ring raceway radius, m,

$Q$ = roller load, N,

$l$ = roller length, m,

$E$ = modulus of elasticity ($= 2.08 \times 10^{11}$ for steel), Pa, and

$\mu$ = Poisson’s ratio ($= 0.3$ for steel).

The pressure-viscosity coefficient $\alpha$ for several lubricant fluids is listed in Table X2.1. The pressure-viscosity coefficient rises with an increase in viscosity.

X2.5 The EHD theory does not consider: (1) changes of the lubricant due to oxidation, and so forth, (2) extraordinary operating conditions (temperature, forces), and (3) environmental influences (fluids, atmosphere, vacuum, dust, and so forth).

X2.6 Please note that the EHD theory describes only the lubricating conditions within the rolling contact and not in the contacts where sliding is involved, for example, between the roller faces and lip surfaces of tapered roller faces and lip surfaces of tapered roller bearings. In such cases, the lubricating conditions are adequately described by the Hydrodynamic Theory.

X2.7 Eq X2.1 shows that the EHD film thickness primarily results from the rolling speed, $\nu$, the absolute viscosity, $\eta$, of the lubricating fluid (base oil of greases) at the operating temperature and atmospheric pressure, and from the pressure-viscosity coefficient, $\alpha$ (see Table X2.1).

X2.8 The Load, $Q$, has little influence because the viscosity rises with increasing loads and the contact surfaces are enlarged due to the elastic deformation of the steel roller elements (Fig. X2.2). This is, however, not the case with hybrid bearings, for example, with ceramic balls. The latter are hardly deformed elastically and do therefore not enlarge the contact area.

X2.9 Elastohydrodynamic Lubricating Regimes

X2.9.1 Parched Regime—This regime is characterized by very thin films that show changes in thickness during operation. Many instrument bearings operate under this condition. In this, mostly oil lubricated, system there is no free bulk lubricant. Lubrication is by a film so thin, by definition, that there is no flow outside the Hertzian contact under service acceleration. The oil flows in this regime only during Hertzian contact, and then only at right angles to the rolling direction, out of the contact. If it is not replaced the film continually thins.

X2.9.2 Starved Regime—Starved lubrication occurs if the contacts are not fully flooded. The lubricant supply is restricted but the system still contains free bulk lubricant. Starved lubrication is primarily used for grease lubricated high-speed rolling element bearings. In the single-charged starved grease contacts an initially high film thickness is followed by a substantial drop in the film thickness.

X2.9.3 Fully Flooded Regime—The lubricant is continuously supplied to the contact inlet in such a quantity that the inlet region is completely filled with the lubricant. The film thickness is in a steady state and the surfaces are completely separated by the lubricant film (Eq X2.1). The bearings reach the longest lifetime under fully flooded conditions.

X2.10 Extended Rating Life Calculation Based on the Ehd Theory for Bearings Operating at Higher Temperatures

X2.10.1 An estimate of bearing life is dependent upon the degree of separation expressed by the life adjustment factor $a_{23}$ of the attainable fatigue life $L_{na}$ (Eq X2.2 and Fig. X2.3) and by the ratio $\kappa$ of the viscosity values at the operating temperature, the so-called operating viscosity $\nu$ and the rated viscosity $\nu_1$, by $a_1$, the life adjustment factor for failure probability, $f$, the temperature factor, and $L$, the rated life:

$$L_{na} = a_1 \cdot a_{23} \cdot f \cdot L$$

(X2.2)

The rated viscosity, $\nu_1$, can be assessed with the diagram in Fig. X2.4 by means of the mean bearing diameter $d_{so}$ (millimetres) and the rotational speed (min$^{-1}$).

X2.10.2 The higher $\kappa$-values are reached when the contact areas between rolling elements and raceways are fully separated by the lubricating film and metal-to-metal contact does
not occur (Zone I, $\kappa < 4$, Fig. X2.3). Under these ideal conditions of lubrication and with a very clean lubricant, the bearing life is primarily determined by the formation of pittings that have their origin in the areas of maximum materials stressing below the raceway surface. If the loads are moderate, which is frequently the case in practice, such bearings are fail-safe. This ideal condition cannot, however, be obtained at low speeds, high loads, and high temperatures, where the lubricating film is too thin to separate the surfaces sufficiently. This regime starts at $\kappa < 4$ and is strongly notable at $\kappa < 0.4$ (Zone II, Fig. X2.3). In this regime with decreasing $\kappa$-values, high wear can no longer be prevented. The lifetime of the bearing and the lubricant will be negatively influenced. Due to the increased metal-to-metal contacts, Zone II requires lubricants of high cleanliness and with adequate lubricating additives for wear reduction and increased load-carrying capacity (parched EHD and starved EHD regime). Zone III is the regime of unfavorable operating conditions, contaminated or unsuitable lubricants, or both.

<table>
<thead>
<tr>
<th>Fluid</th>
<th>$\alpha$-Value, GPa$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral oil (paraffin-naphthenic)</td>
<td>21</td>
</tr>
<tr>
<td>Mineral oil (naphthenic-aromatic)</td>
<td>30</td>
</tr>
<tr>
<td>Polyalphaolefin</td>
<td>18</td>
</tr>
<tr>
<td>Diester (2-ethylhexyladipate)</td>
<td>7.6</td>
</tr>
<tr>
<td>Polyolester (pentaerythritetravalerate)</td>
<td>7.5</td>
</tr>
<tr>
<td>Polydimethylsilicone</td>
<td>2.3</td>
</tr>
<tr>
<td>PFPE–straight</td>
<td>4–12</td>
</tr>
<tr>
<td>PFPE–branched</td>
<td>26–36</td>
</tr>
</tbody>
</table>

FIG. X2.2 Schematic of EHD Lubricating Film and Surface Deformation in a Roller/Inner Ring Contact
FIG. X2.3 Attainable Fatigue Life

FIG. X2.4 Rated Viscosity, $\nu_1$
### X. MILITARY SPECIFICATION AND SOURCES FOR OILS TESTED

#### TABLE X.1 Military Specification and Sources for Oils Tested

<table>
<thead>
<tr>
<th>Lubricant</th>
<th>Military Specification</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anderol 401D</td>
<td>MIL-L-6085</td>
<td>Huls</td>
</tr>
<tr>
<td>Bendix Pioneer P-10</td>
<td>MIL-L-6085</td>
<td></td>
</tr>
<tr>
<td>Bray 814</td>
<td>none</td>
<td>Castrol</td>
</tr>
<tr>
<td>Bray 815Z</td>
<td>none</td>
<td>Castrol</td>
</tr>
<tr>
<td>Bray 885</td>
<td>MIL-L-14107</td>
<td>Castrol</td>
</tr>
<tr>
<td>Castrol 5050</td>
<td>MIL-L-23699</td>
<td>Castrol</td>
</tr>
<tr>
<td>Castrol 399</td>
<td>MIL-L-7808</td>
<td>Castrol</td>
</tr>
<tr>
<td>Coray 100</td>
<td>none</td>
<td>Exxon</td>
</tr>
<tr>
<td>Dow Corning Q5-0161</td>
<td>none</td>
<td>Dow Corning</td>
</tr>
<tr>
<td>DC FS-1265, 300 cSt</td>
<td>none</td>
<td>Dow Corning</td>
</tr>
<tr>
<td>Dow Corning DC710</td>
<td>none</td>
<td>Dow Corning</td>
</tr>
<tr>
<td>DC 510, 50 cSt</td>
<td>none</td>
<td>Dow Corning</td>
</tr>
<tr>
<td>DC 200, 50 cSt</td>
<td>none</td>
<td>Dow Corning</td>
</tr>
<tr>
<td>DuPont Krytox 143AC</td>
<td>none</td>
<td>Dow Corning</td>
</tr>
<tr>
<td>Prosil M20</td>
<td>MIL-S-81804</td>
<td>PCR</td>
</tr>
<tr>
<td>Grignard TN-3</td>
<td>MIL-L-81846</td>
<td>Grignard</td>
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<tr>
<td>Kluber Barrierta FOY 150</td>
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<td>Kluber</td>
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<tr>
<td>Barrierta 1 EL</td>
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<td>Kluber</td>
</tr>
<tr>
<td>Barrierta 1 MI</td>
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<td>Kluber</td>
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<tr>
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<td>Kluber</td>
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<tr>
<td>Kluber Isoflex</td>
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<td>Isoflex All Time 28</td>
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<tr>
<td>Mobil 624</td>
<td>none</td>
<td>Mobil Chemical</td>
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<tr>
<td>Mobil 743A</td>
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<td>Mobil 61</td>
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<tr>
<td>Mobil 714 SHF</td>
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<td>Mobil Chemical</td>
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<tr>
<td>Mobil DTE</td>
<td>none</td>
<td>Mobil Oil</td>
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<tr>
<td>Nye Synthetic Oil 132</td>
<td>MIL-L-53131 Grade 4</td>
<td>Nye Lubricants, Inc.</td>
</tr>
<tr>
<td>Nye Synthetic Oil 176A</td>
<td>MIL-L-53131 Grade 40</td>
<td>Nye Lubricants, Inc.</td>
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<tr>
<td>Nye Synthetic Oil 176H</td>
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<td>Nye Lubricants, Inc.</td>
</tr>
<tr>
<td>Nye Synthetic Oil 176M</td>
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<td>Nye Lubricants, Inc.</td>
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<tr>
<td>Nye Synthetic Oil 179A</td>
<td>MIL-DTL-53131 Grade 6</td>
<td>Nye Lubricants, Inc.</td>
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<tr>
<td>Nye Synthetic Oil 182</td>
<td>MIL-DTL-53131 Grade 9</td>
<td>Nye Lubricants, Inc.</td>
</tr>
<tr>
<td>Nye Synthetic Oil 186</td>
<td>MIL-DTL-53131 Grade 14</td>
<td>Nye Lubricants, Inc.</td>
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<tr>
<td>Nye Synthetic Oil 500R</td>
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<td>Nye Lubricants, Inc.</td>
</tr>
<tr>
<td>Nye NPE-UC4</td>
<td>none</td>
<td>Nye Lubricants, Inc.</td>
</tr>
<tr>
<td>Nye NPE-UC7</td>
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<td>Nye Lubricants, Inc.</td>
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<tr>
<td>Nye NPE-UC9</td>
<td>none</td>
<td>Nye Lubricants, Inc.</td>
</tr>
<tr>
<td>Winsor Lube L245X</td>
<td>MIL-L-6085</td>
<td>Metal Lubricants</td>
</tr>
</tbody>
</table>

---

See notes below:

- Degussa Corporation, 4201 Degussa Rd., Theodore, AL 36582.
- Castrol Industrial North America, Inc., Headquarters, 1001 West 31st St., Downers Grove, IL 60515.
- ExxonMobil Chemical Company, 13501 Katy Freeway, Houston, TX 77079–1398.
- Dow Corning Corp., Corporate Center, PO Box 994, Midland, MI 48686–0994.
- Grignard, 900 Port Reading Ave., Port Reading, NJ 07094.
- Kluber Lubrication North America, 54 Wentworth Ave., Londonberry, NH 03053.
- Ferro Corp., Route 130 South, Bridgeport, NJ 08014.
Standard Specification for
Bearing, Roller, Needle: Drawn Outer Ring, Full
Complement, Without Inner Ring, Open and Closed End,
Standard Type

This standard is issued under the fixed designation F 2162; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

e1 NOTE—Note 1 was changed editorially in June 2002.
e2 NOTE—Table 1 was editorially corrected in May 2003.

1. Scope

1.1 This specification covers standard-type needle roller
bearings having drawn outer rings, full complement, without
inner rings, with either open or closed ends.

1.2 The use of recycled materials that meet the requirements
of the applicable material specification without jeopardizing
the intended use of the item is encouraged.

1.3 The inner rings specified in this specification are not
intended for use in flight critical systems of aircraft.

1.4 The values stated in inch-pound units are to be regarded
as the standard. The values given in parentheses are provided
for information only.

Note 1—This specification contains many of the requirements
of MS17131, which was originally developed by the Department of Defense and is currently maintained by the Defense Supply Center Richmond.

2. Referenced Documents

2.1 ASTM Standards:
E 18 Test Methods for Rockwell Hardness and Rockwell
Superficial Hardness of Metallic Materials
E 140 Standard Hardness Conversion Tables for Metals
(Relationship Among Brinell Hardness, Vickers Hardness,
Rockwell Hardness, Rockwell Superficial Hardness,
Knoop Hardness, and Scleroscope Hardness)
E 384 Test Method for Microindentation Hardness
F 2163 Specification for Ring, Bearing, Inner: for Needle
Roller Bearing With Drawn Outer Ring

2.2 ASME Standard:
ASME B 46.1 Surface Texture Surface Roughness, Waviness,
and Lay

2.3 SAE Standard:
SAE J-404 Chemical Composition of SAE Alloy Steels
2.4 Military Standard:
MIL-STD-130 Identification Marking of US Military Property
2.5 American Bearing Manufacturer’s Association (ABMA)
Standard:
STD 4 Tolerance Definitions and Gauging Practices For
Ball and Roller Bearings
2.6 ISO Standards:
ISO 5593 Rolling Bearings—Vocabulary
ISO 1132 Rolling Bearings—Tolerances—Definitions

3. Terminology

3.1 Definitions—For definitions of terms used in this speci-
fication, refer to ABMA STD 4 Tolerance Definitions and
Gauging Practices for Ball and Roller Bearings, ISO 1132
Roller Bearings—Tolerances—Definitions, and to ISO 5593
Rolling Bearings—Vocabulary

3.2 Definitions of Terms Specific to This Standard:
3.2.1 average life (L<sub>50</sub>)<sup>1</sup>, n—for a radial roller bearing, the
number of revolutions that 50 % of a group of bearings will
complete or exceed before the first evidence of fatigue devel-
ops.

3.2.1.1 Discussion—The average life may be as much as five
times the rating life.

---

1 This specification is under the jurisdiction of ASTM Committee F34 on Rolling
Element Bearings and is the direct responsibility of Subcommittee F34.01 on
Rolling Element.


2 Annual Book of ASTM Standards, Vol 03.01.

3 Available from Global Engineering Documents, 15 Inverness Way, East
Englewood, CO 80112.
3.2.2 basic dynamic load rating \((C_r)\), \(n\)—for a radial roller bearing, that calculated, constant radial load that a group of apparently identical bearings with stationary outer rings can theoretically endure for a rating life of one million revolutions of the inner ring.

3.2.2.1 Discussion—Since applied loading as great as the basic dynamic load rating tends to cause local plastic deformation of the rolling surfaces, it is not anticipated that such heavy loading would normally be applied.

3.2.3 basic static load rating \((C_s)\), \(n\)—for a radial roller bearing, that uniformly distributed static radial load which produces a maximum contact stress of 580,000 psi \((4000 \text{ Mpa})\) at the center of the contact of the most heavily loaded rolling element.

3.2.3.1 Discussion—For this contact stress, total permanent deformation of rolling element and raceway occurs which is approximately 0.0001 or the roller diameter.

3.2.4 rating life \((L_{10})\), \(n\)—for a radial roller bearing, the number of revolutions that 90% of a group of bearings will complete or exceed before the first evidence of fatigue develops.

4. Classification

4.1 This specification covers the following types of roller bearings:

4.1.1 Type B—Open end roller bearings, and

4.1.2 Type M—Closed end roller bearings.

5. Ordering Information

5.1 When ordering parts in accordance with this specification, specify the following:

5.1.1 ASTM designation number, including year of issue,

5.1.2 Type, whether Type B or Type M roller bearings (see Section 4) are to be furnished,

5.1.3 Dash number (see Table 1),

5.1.4 Dimensions of roller bearings, including:

5.1.4.1 Bore diameter, in;

5.1.4.2 Ring gage diameter, in;

5.1.4.3 Width, in; and

5.1.4.4 Shaft diameter, in;

5.1.5 Load rating, including basic static load rating, lb and basic dynamic load rating, lb;

5.1.6 Approximate limiting speed, rpm; and

5.1.7 Maximum end thickness.

6. Materials and Manufacture

6.1 Needle Rollers—Needle rollers shall be manufactured of steel, alloy or carbon, of grades E50100 or E52100 in accordance with SAE AHS STD-66, or 1090 or 1095 in accordance with SAE J-404.

6.2 Rings—Rings shall be manufactured of steel, alloy, or carbon, carburizing grade 4620, 4720, 8620, 8720, or 1010-1020 in accordance with SAE AHS STD-66.

7. Other Requirements

7.1 Heat Treatment:

7.1.1 Needle Rollers—Needle rollers shall be through-hardened to Rockwell HRC58 or equivalent, in accordance with Test Methods E 18.

7.1.2 Rings—Rings shall be case hardened to surface hardness of Rockwell HRC58-65 or equivalent, in accordance with Test Methods E 18 with a 0.003 in. minimum case depth.

7.1.2.1 This case depth will not support Rockwell HR15N. Use of a standard file test in accordance with SAE J-864 or microsection and microhardness test in accordance with Test Method E 18 is required to determine the surface hardness.

7.1.3 Shafts—Bearings are intended to be used with shafts hardened to Rockwell HRC58-65 in accordance with Test Methods E 18.

7.1.3.1 When an open end bearing is used with an unhardened shaft, the bearing shall be used in conjunction with an inner bearing ring (F 2163).

7.2 Protective Coating:

7.2.1 Needle rollers and rings shall be furnished without plating.

7.2.2 Manufacturer shall coat bearings with rust preventive film.

7.3 Lubrication—Bearings shall be furnished without lubrication.

7.4 Rollers shall be retained by the outer ring.

7.5 Bearings shall not be furnished with roller separators.

7.6 Oil holes shall be furnished in accordance with the manufacturer’s standard practice.

8. Dimensions, Mass, and Permissible Variations

8.1 Products manufactured in accordance with this specification shall meet the requirements shown in Table 1.

8.2 Plug Gages—The “go” plug gage is the same size as the minimum diameter under the needle rollers column in Table 1, and the “no go” plug gage size is 0.0001 in. larger than the maximum diameter under the needle rollers column in Table 1. Inspection of the bearing bore shall be made with the bearing pressed into a ring gage of the size shown in the ring gage diameter column of Table 1.
F 2162 – 01e2
TABLE 1 Roller Bearing Dimensions and Tolerances
Fw
Bore Diameter, in.

Dash Number
Type
B
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
–12
–13
–14
–64
–65
–15
–16
–17
–18
–19
–66
–67
–20
–21
–22
–23
–68
–24
–25
–69
–26
–27
–28
–70
–71
–29
–30
–31
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–33
–34
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–38
–39
–40
–41
–42
–43
–44
–45
–46
–47
–48
–49
–50
–51
–52
–72
–53
–54
–55
–56
–57
–58
–59
–60
–61
–62
–63

Type
M
–1M
–2M
–3M
–4M
–5M
–6M
–7M
–8M
–9M
–10M
–11M
–12M
–13M
–14M
–64M
–65M
–15M
–16M
–17M
–18M
–19M
–66M
–67M
–20M
–21M
–22M
–23M
–68M
–24M
–25M
–69M
–26M
–27M
–28M
–70M
–71M
–29M
–30M
–31M
–32M
–33M
–34M
–35M
–36M
–37M
–38M
–39M
–40M
–41M
–42M
–43M
–44M
–45M
–46M
–47M
–48M
–49M
–50M
–51M
–52M
–72M
–53M
–54M
–55M
–56M
–57M
–58M
–59M
–60M
–61M
–62M
–63M

D
Diameter, in.

Nom.

Min.

Max.

Ring
Gage

⁄
⁄
3⁄16
3⁄16
1⁄4
1⁄4
5⁄16
5⁄16
3⁄8
3⁄8
7⁄16
1⁄2
1⁄2
1⁄2
1⁄2
1⁄2
9⁄16
9⁄16
9⁄16
5⁄8
5⁄8
5⁄8
5⁄8
11⁄16
11⁄16
3⁄4
3⁄4
13⁄16
13⁄16
13⁄16
7⁄8
7⁄8
7⁄8
15⁄16
1
1
1
1
11⁄16
11⁄8
11⁄8
13⁄16
11⁄4
11⁄4
15⁄16
15⁄16
13⁄8
13⁄8
11⁄2
11⁄2
11⁄2
15⁄8
15⁄8
13⁄4
13⁄4
13⁄4
17⁄8
17⁄8
2
2
21⁄16
21⁄8
21⁄8
21⁄4
21⁄4
21⁄2
25⁄8
23⁄4
23⁄4
31⁄2
51⁄2
71⁄4

0.1258
0.1571
0.1883
0.1883
0.2515
0.2515
0.3140
0.3140
0.3765
0.3765
0.4390
0.5015
0.5015
0.5015
0.5015
0.5015
0.5640
0.5640
0.5640
0.6265
0.6265
0.6265
0.6265
0.6890
0.6890
0.7505
0.7505
0.8130
0.8130
0.8130
0.8755
0.8755
0.8755
0.9380
1.0005
1.0005
1.0005
1.0005
1.0630
1.1255
1.1255
1.1880
1.2505
1.2505
1.3130
1.3130
1.3755
1.3755
1.5005
1.5005
1.5005
1.6255
1.6255
1.7505
1.7505
1.7505
1.8755
1.8755
2.0006
2.0006
2.0635
2.1256
2.1256
2.2506
2.2506
2.5006
2.6260
2.7510
2.7510
3.5010
5.5010
7.2510

0.1267
0.1580
0.1892
0.1892
0.2524
0.2524
0.3149
0.3149
0.3774
0.3774
0.4399
0.5024
0.5024
0.5024
0.5024
0.5024
0.5649
0.5649
0.5649
0.6274
0.6274
0.6274
0.6274
0.6899
0.6899
0.7514
0.7514
0.8139
0.8139
0.8139
0.8764
0.8764
0.8764
0.9389
1.0014
1.0014
1.0014
1.0014
1.0639
1.1264
1.1264
1.1889
1.2514
1.2514
1.3140
1.3140
1.3765
1.3765
1.5016
1.5016
1.5016
1.6266
1.6266
1.7517
1.7517
1.7517
1.8767
1.8767
2.0018
2.0018
2.0649
2.1270
2.1270
2.2520
2.2520
2.5020
2.6274
2.7524
2.7524
3.5024
5.5029
7.2530

0.2505
0.2817
0.3437
0.3437
0.4380
0.4380
0.5005
0.5005
0.5630
0.5630
0.6255
0.6880
0.6880
0.6880
0.6880
0.6880
0.7505
0.7505
0.7505
0.8130
0.8130
0.8130
0.8130
0.8755
0.8755
0.9995
0.9995
1.0620
1.0620
1.0620
1.1245
1.1245
1.1245
1.1870
1.2495
1.2495
1.2495
1.2495
1.3120
1.3745
1.3745
1.4995
1.4995
1.4995
1.6245
1.6245
1.6245
1.6245
1.8745
1.8745
1.8745
1.9995
1.9995
2.1245
2.1245
2.1245
2.2495
2.2495
2.3745
2.3745
2.5307
2.4995
2.4995
2.6245
2.6245
2.8795
2.9995
3.1245
3.1245
3.9995
5.9990
7.7490

18

5 32

C
Width, in.
Outside +0.000 -0.010
Nom.
⁄

14

⁄

9 32

⁄
⁄

11 32
11 32

⁄
⁄

7 16
7 16

⁄
⁄

12
12

⁄
⁄

9 16
9 16

⁄
⁄
11⁄16
11⁄16
11⁄16
11⁄16
3⁄4
3⁄4
3⁄4
13⁄16
13⁄16
13⁄16
13⁄16
7⁄8
7⁄8
1
1
1
1 ⁄16
1
1 ⁄16
11⁄16
11⁄8
11⁄8
11⁄8
13⁄16
11⁄4
11⁄4
11⁄4
11⁄4
15⁄16
13⁄8
13⁄8
11⁄2
11⁄2
11⁄2
15⁄8
15⁄8
15⁄8
15⁄8
17⁄8
17⁄8
17⁄8
2
2
21⁄8
21⁄8
21⁄8
21⁄4
21⁄4
23⁄8
23⁄8
217⁄32
21⁄2
21⁄2
25⁄8
25⁄8
27⁄8
3
31⁄8
31⁄8
4
6
73⁄4
58

11 16

0.250
0.312
0.250
0.375
0.312
0.438
0.312
0.438
0.375
0.500
0.500
0.375
0.500
0.750
0.312
0.625
0.375
0.500
0.750
0.500
0.750
0.312
0.438
0.500
0.750
0.500
0.750
0.375
0.500
1.000
0.500
0.750
1.000
1.000
0.438
0.500
0.750
1.000
0.625
0.750
1.000
0.625
1.000
1.250
0.500
0.625
0.750
1.250
0.625
1.000
1.250
0.625
1.250
0.750
1.000
1.500
0.500
1.000
1.000
1.750
1.500
1.000
1.500
0.750
1.500
1.500
1.000
1.000
1.250
0.750
0.750
0.750

Shaft Diameter,
in.
Min.

Max.

0.1247
0.1560
0.1872
0.1872
0.2495
0.2495
0.3120
0.3120
0.3745
0.3745
0.4370
0.4995
0.4995
0.4995
0.4995
0.4995
0.5620
0.5620
0.5620
0.6245
0.6245
0.6245
0.6245
0.6870
0.6870
0.7495
0.7495
0.8120
0.8120
0.8120
0.8745
0.8745
0.8745
0.9370
0.9995
0.9995
0.9995
0.9995
1.0620
1.1245
1.1245
1.1870
1.2495
1.2495
1.3120
1.3120
1.3745
1.3745
1.4995
1.4995
1.4995
1.6245
1.6245
1.7495
1.7495
1.7495
1.8745
1.8745
1.9994
1.9994
2.0619
2.1244
2.1244
2.2494
2.2494
2.4994
2.6244
2.7494
2.7494
3.4994
5.4993
7.2490

0.1250
0.1563
0.1875
0.1875
0.2500
0.2500
0.3125
0.3125
0.3750
0.3750
0.4375
0.5000
0.5000
0.5000
0.5000
0.5000
0.5625
0.5625
0.5625
0.6250
0.6250
0.6250
0.6250
0.6875
0.6875
0.7500
0.7500
0.8125
0.8125
0.8125
0.8750
0.8750
0.8750
0.9375
1.0000
1.0000
1.0000
1.0000
1.0625
1.1250
1.1250
1.1875
1.2500
1.2500
1.3125
1.3125
1.3750
1.3750
1.5000
1.5000
1.5000
1.6250
1.6250
1.7500
1.7500
1.7500
1.8750
1.8750
2.0000
2.0000
2.0625
2.1250
2.1250
2.2500
2.2500
2.5000
2.6250
2.7500
2.7500
3.5000
5.5000
7.2500

3

Basic Static Basic Dynamic
Approximate
X
Load Rating, Load Rating, Limiting Speed, End Thickness,
lb
lb
rpm
in., max
221
387
283
575
482
865
578
1040
941
1480
1690
1210
1900
3280
867
2590
1340
2110
3640
2320
4010
1060
1900
2530
4370
2630
4700
1710
2820
7280
3020
5400
7780
8280
2730
3410
6100
8780
5020
6790
9790
5100
10 800
14 100
3840
5590
8190
15 400
6200
12 300
16 300
6620
17 500
9400
14 000
23 300
5140
15 000
15 900
31 700
267 00
16 800
28 000
12 000
29 600
32 700
20 600
21 600
28 700
16 900
25 100
32 700

236
374
309
537
498
786
573
903
826
1180
1280
968
1380
2100
748
1750
1030
1470
2240
1560
2380
846
1330
1640
2510
2000
3140
1410
2090
4360
2170
3420
4540
4720
1980
2350
3690
4900
3140
3930
5220
3430
5530
6800
2710
3630
4370
7140
4220
7170
8940
4350
9260
5620
7880
11 400
3500
6080
6300
14 200
14 000
8510
12 600
6570
13 300
13 900
9570
9870
12 300
9270
10 800
12 500

12 500
10 700
10 700
10 700
10 000
10 000
8300
8300
7100
7100
6300
5500
5500
5500
5500
5500
5000
5000
5000
4500
4500
4500
4500
4200
4200
5300
5300
5200
5000
5000
4800
4500
4500
4400
4300
4300
4100
4100
3800
3600
3600
4400
3300
3300
4000
4000
3000
3000
4300
4300
4300
3900
3900
3600
3600
3600
3500
3500
3300
3300
4000
3000
3000
3000
3000
2700
2500
2500
2500
2700
1600
1200

0.05
0.05
0.07
0.07
0.08
0.08
0.08
0.08
0.08
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0.08
0.08
0.08
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0.09
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0.09
0.11
0.09
0.09
0.11
0.11
0.09
0.09
0.12
0.12
0.12
0.12
0.12
0.12
0.12
0.12
0.12
0.12
0.12
0.12
0.14
0.12
0.12
0.13
0.13
...
0.13
0.13
0.13
0.15
...
...


8.3 Bearings are intended to be installed on shafts where maximum deflection does not exceed 0.0010 in. per inch of bearing width.

8.4 Applications involving oscillating motion often require reduced radial clearances. This reduction is accomplished by increasing the shaft raceway diameters, in inches, as follows:

<table>
<thead>
<tr>
<th>Increase in Shaft Raceway</th>
<th>For Bearings with Bore Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0003</td>
<td>1/32–9/32</td>
</tr>
<tr>
<td>0.0005</td>
<td>1/16–1/4</td>
</tr>
<tr>
<td>0.0006</td>
<td>2–5/8</td>
</tr>
</tbody>
</table>

8.5 Steel housing bore diameter dimensions, in inches, are as follows:

<table>
<thead>
<tr>
<th>Tolerance Applied to Ring Gage Diameter</th>
<th>Diameters of Steel Housing Bore Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>+0.0000–0.0005</td>
<td>+1/32–3/32</td>
</tr>
<tr>
<td>+0.0010 /–0.0000</td>
<td>1–5</td>
</tr>
<tr>
<td>+0.0020/–0.0000</td>
<td>+5/32–1</td>
</tr>
</tbody>
</table>

8.6 Mounting in conformance with the shaft diameters and housing bore diameters, in inches, results in the following clearances:

<table>
<thead>
<tr>
<th>Radial Clearances</th>
<th>For Bearings with Bore Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0003–0.0020</td>
<td>1/32–1/8</td>
</tr>
<tr>
<td>0.0005–0.0029</td>
<td>1/16–1/4</td>
</tr>
<tr>
<td>0.0005–0.0030</td>
<td>5/32–1</td>
</tr>
<tr>
<td>0.0005–0.0031</td>
<td>1/16–11/16</td>
</tr>
<tr>
<td>0.0005–0.0032</td>
<td>11/16–11/16</td>
</tr>
<tr>
<td>0.0006–0.0034</td>
<td>2</td>
</tr>
<tr>
<td>0.0006–0.0036</td>
<td>21/16–21/16</td>
</tr>
<tr>
<td>0.0010–0.0040</td>
<td>21/16–31/16</td>
</tr>
<tr>
<td>0.0010–0.0056</td>
<td>71/16</td>
</tr>
<tr>
<td>0.0010–0.0059</td>
<td>7/32</td>
</tr>
</tbody>
</table>

9. Workmanship, Finish and Appearance

9.1 Surface Finish:

9.1.1 Needle Rollers—Needle rollers shall have a maximum surface roughness in accordance with ASME B46.1 of 8 µin. Ra.

9.1.2 Rings—The raceway surface (bore) of the outer ring shall have a maximum surface roughness, in accordance with ANSI B46.1, of 20 µin. Ra.

10. Rating Life of Roller Bearing

10.1 Use the following equation to calculate rating life of roller bearing, \( L_{10} \), in millions of revolutions, at loads other than the basic dynamic load ratings:

\[
L_{10} = \frac{[C_r/P]}{[10/3]} \tag{1}
\]

where:

\( L_{10} \) = Rating life, \( 10^6 \) revolutions;
\( C_r \) = basic dynamic load rating, lb; and
\( P \) = equivalent radial load to which bearing is subjected, lb.

10.1.1 The rating life of roller bearings as calculated in Eq 1 are assumed to be operating under the following conditions:

10.1.1.1 The inner ring is rotating,
10.1.1.2 The outer ring is stationary,
10.1.1.3 The load is steady,
10.1.1.4 The revolutions per minute are uniform,
10.1.1.5 The roller bearing is thoroughly lubricated,
10.1.1.6 The maximum bearing temperature does not exceed 300°F, and
10.1.1.7 Any shaft misalignment does not exceed 0.0010 in. per inch of bearing width.

10.1.2 Eq 1 is not valid for an applied load greater than one-half the basic dynamic load rating.

11. Inspection

11.1 Inspection of the product shall be agreed upon between the purchaser and the supplier as part of the purchase contract.

12. Rejection and Rehearing

12.1 Products that fail to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for rehearing.

13. Certification

13.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

14. Product Marking

14.1 Marking shall consist of the part number and the manufacturer’s identification in accordance with MIL-STD 130.

14.1.1 The part number shall consist of the MS17131 designation number plus the dash number (see Table 1).

15. Keywords

15.1 drawn outer ring; full complement bearing; needle bearing; MS17131; roller bearing

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

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Standard Specification for
Ring, Bearing, Inner: for Needle Roller Bearing With Drawn Outer Ring

This standard is issued under the fixed designation F 2163; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε1 Note—Note 1 was changed editorially in June 2002.

1. Scope

1.1 This specification covers inner rings for needle roller bearings with drawn outer rings.

1.2 The inner rings specified in this specification are intended for use on unhardened shafts in conjunction with open end needle roller bearings shown on Specification F 2162 and MS52141.

1.3 The use of recycled materials that meet the requirements of the applicable material specification without jeopardizing the intended use of the item is encouraged.

1.4 The inner rings specified in this specification are not intended for use in flight-critical systems of aircraft.

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information only.

Note 1—This specification contains many of the requirements of MS17130, which was originally developed by the Department of Defense and is currently maintained by the Defense Supply Center Richmond.

2. Referenced Documents

2.1 ASTM Standards:
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
F 2162 Specification for Bearing, Roller, Needle: Drawn Outer Ring, Full Complement, Without Inner Ring, Open and Closed End, Standard Type
2.2 ASME Standard:
ASME B 46.1 Surface Texture Surface Roughness, Waviness, and Lay
2.3 SAE Standards:
SAE AHS STD-66
SAE J-404 Chemical Composition of SAE Alloy Steels

2.4 Military Standards:
MIL-STD-130 Identification Marking of US Military Property
MS52141 Bearing, Roller, Needle: Drawn Outer Ring, Caged, Without Inner Ring, Open and Closed End, Standard Type
2.5 American Bearing Manufacturer’s Association (ABMA) Standard:
STD 4 Tolerance Definitions and Gauging Practices For Ball and Roller Bearings
2.6 ISO Standard:
ISO 5593 Rolling Bearings—Vocabulary

3. Terminology

3.1 Definitions—For definitions of terms used in this specification, refer to ABMA STD 4 and ISO 5593.

4. Ordering Information

4.1 When ordering parts in accordance with this specification, specify the following:
4.1.1 ASTM designation number, including year of issue;
4.1.2 Dash number (see Table 1); and
4.1.3 Dimensions of inner rings, including:
4.1.3.1 Bore diameter, in.;
4.1.3.2 Outside diameter, in.;
4.1.3.3 Width, in.; and
4.1.3.4 Radius, in.

5. Materials and Manufacture

5.1 Bearing inner rings shall be manufactured of steel, alloy or carbon, carburizing grade 4620, 4720, 8620, 8720, or 1018, 1022, or 1117 in accordance with SAE AHS STD-66 or SAE E52100 in accordance with SAE J-404.

6. Other Requirements

6.1 Heat Treatment:

---

1 This specification is under the jurisdiction of ASTM Committee F34 on Rolling Element Bearings and is the direct responsibility of Subcommittee F34.01 on Rolling Element.


2 Annual Book of ASTM Standards, Vol 03.01.

3 Annual Book of ASTM Standards, Vol 01.08.


5 Available from SAE International, 400 Commonwealth Dr., Warrendale, PA 15096-0001.

6 Available from USA Information Systems, 1092 Laskin Rd., Ste. 208, Virginia Beach, VA 23451.

7 Available from the American Bearing Manufacturer’s Association, 1200 19th St. NW, Ste. 300, Washington, DC 20036–2401.

8 Available from ANSI, 1819 L St. NW, Ste. 600, Washington, DC 20036.
6.1.1 Steel 4620, 4720, 8620, 8720, 1018, 1022, and 1117 shall be case hardened to Rockwell HRC58-65, in accordance with Test Methods E 18. Case depth shall be 0.020 minimum.

6.1.2 Steel SAE 52100 shall be through hardened to Rockwell HRC58-65, in accordance with Test Methods E 18.

6.2 Protective Coating:

6.2.1 Unless specified, plain (that is, not plated) inner rings shall be furnished.

6.2.2 Manufacturer shall coat inner rings with rust-preventative film.

6.3 Lubrication:

6.3.1 Oil hole(s), number (1 to 4) and size optional.

6.3.2 An oil groove, centered in the inner ring bore, is optional in accordance with manufacturer’s standard practice.

7. Dimensions, Mass, and Permissible Variations

7.1 Products manufactured in accordance with this specification shall meet the requirements shown in Table 1.

7.1.1 Given the shaft diameter and radial load for a particular bearing application, the bore diameter of the inner ring is selected from the shaft size. The outer diameter and width are chosen by dimensionally mating the inner ring with the outer ring (see Specification F 2162 or MS52141) that exhibits the required load capacity.

7.2 The taper in the shaft shall not exceed 0.0003 in. per inch of bearing length.

7.3 The inner ring must clear the maximum shaft fillet radius shown in the radius column of Table 1. The radii or chamfers on the inner diameter of the ring may be unequal. Where the radii are unequal, the surface with the larger relief should be mounted against the shaft shoulder.

8. Workmanship, Finish and Appearance

8.1 Surface Finish—The raceway (outside diameter) surface shall have a maximum surface roughness in accordance with ASME B46.1 of 20 μin. Ra.

9. Inspection

9.1 Inspection of the product shall be agreed upon between the purchaser and the supplier as part of the purchase contract.

---

### TABLE 1 Inner Ring Dimensions

<table>
<thead>
<tr>
<th>Dash Number</th>
<th>Bore Diameter, in.</th>
<th>Outside Diameter, in.</th>
<th>Width, in.</th>
<th>Radius, in.</th>
<th>Mating Bearings F 2162 Dash Numbers</th>
<th>F 2163</th>
</tr>
</thead>
<tbody>
<tr>
<td>–61</td>
<td>3/8</td>
<td>0.3745</td>
<td>0.3750</td>
<td>9/16</td>
<td>0.5620 0.5625 0.505 0.515</td>
<td>0.025 –16</td>
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<tr>
<td>–62</td>
<td>3/8</td>
<td>0.3745</td>
<td>0.3750</td>
<td>9/16</td>
<td>0.5620 0.5625 0.755 0.765</td>
<td>0.025 –17</td>
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<tr>
<td>–63</td>
<td>3/8</td>
<td>0.3745</td>
<td>0.3750</td>
<td>5/8</td>
<td>0.6245 0.6250 0.505 0.515</td>
<td>0.025 –18</td>
</tr>
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<td>–1</td>
<td>3/8</td>
<td>0.3745</td>
<td>0.3750</td>
<td>5/8</td>
<td>0.6245 0.6250 0.755 0.765</td>
<td>0.025 –19</td>
</tr>
<tr>
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<td>1/4</td>
<td>0.4370</td>
<td>0.4375</td>
<td>5/8</td>
<td>0.6245 0.6250 0.755 0.765</td>
<td>0.025 –20</td>
</tr>
<tr>
<td>–65</td>
<td>1/4</td>
<td>0.4995</td>
<td>0.5000</td>
<td>5/8</td>
<td>0.7495 0.7500 0.505 0.515</td>
<td>0.040 –22</td>
</tr>
<tr>
<td>–2</td>
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<td>0.4995</td>
<td>0.5000</td>
<td>5/8</td>
<td>0.7495 0.7500 0.755 0.765</td>
<td>0.040 –23</td>
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<tr>
<td>–4</td>
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<td>0.6840</td>
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<td>0.040 –24</td>
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<tr>
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<td>0.6245</td>
<td>0.6250</td>
<td>7/8</td>
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<td>0.040 –27</td>
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<tr>
<td>–67</td>
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<td>0.7495</td>
<td>0.7500</td>
<td>1</td>
<td>0.9995 1.0000 1.005 1.015</td>
<td>0.040 –30</td>
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<tr>
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<tr>
<td>–7</td>
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</tr>
<tr>
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<td>0.8750</td>
<td>11/32</td>
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<td>1.0000</td>
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<tr>
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<tr>
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<td>1.1250</td>
<td>11/32</td>
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</tr>
<tr>
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<tr>
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<td>1.2500</td>
<td>11/32</td>
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<td>0.060 –42</td>
</tr>
<tr>
<td>–16</td>
<td>11/32</td>
<td>1.2495</td>
<td>1.2500</td>
<td>11/32</td>
<td>1.4995 1.5000 1.255 1.265</td>
<td>0.060 –43</td>
</tr>
<tr>
<td>–18</td>
<td>11/32</td>
<td>1.3745</td>
<td>1.3750</td>
<td>11/32</td>
<td>1.6245 1.6250 1.255 1.265</td>
<td>0.060 –45</td>
</tr>
<tr>
<td>–21</td>
<td>11/32</td>
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<td>11/32</td>
<td>1.7495 1.7500 1.005 1.015</td>
<td>0.060 –47</td>
</tr>
<tr>
<td>–69</td>
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<td>11/32</td>
<td>1.7495 1.7500 1.505 1.515</td>
<td>0.060 –48</td>
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<td>1.5000</td>
<td>11/32</td>
<td>1.7495 1.7500 1.505 1.515</td>
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<tr>
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<td>21/32</td>
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<td>21/32</td>
<td>2.1245 2.1250 1.505 1.515</td>
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<td>21/32</td>
<td>2.7495 2.7500 1.005 1.015</td>
<td>0.060 –59</td>
</tr>
</tbody>
</table>

*Dash numbers for mating bearings as specified in 7.1.1 of F 2162.*
10. Rejection and Rehearing

10.1 Products that fail to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for rehearing.

11. Certification

11.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

12. Product Marking

12.1 Marking shall consist of the part number and the manufacturer's identification in accordance with MIL-STD 130.

12.2 On inner rings where the inside diameter relief radii are not equal, the marking shall appear on the surface with the lesser radius.

12.3 The part number shall consist of the MS17130 designation number plus the dash number (see Table 1).

13. Keywords

13.1 drawn outer ring; inner ring; MS 17130; needle roller bearing
Standard Specification for
Balls, Bearings, Ferrous and Nonferrous for Use in
Bearings, Valves, and Bearing Applications

This standard is issued under the fixed designation F 2215; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers requirements for ferrous and
nonferrous inch balls. The balls covered in this specification
are intended for use in bearings, bearing applications, check
valves, and other components using balls.

1.2 This is a general specification. The individual item
requirements shall be as specified herein in accordance with the
Annex A2 through Annex A9 MS sheet standards. In the event
of any conflict between requirements of this specification and
the Annex A2 through Annex A9 MS sheet standards, the latter
shall govern.

1.3 The values given in inch-pound units are to be regarded
as standard. The values given in parentheses are for informa-
tion only.

1.4 This specification contains many of the requirements of
MIL-B-1083, which was originally developed by the Depart-
ment of Defense and maintained by the Defense Supply Center
Richmond. The following government activity codes may be
found in the Department of Defense, Standardization Directory
SD-1.2

Preparing Activity
DLA-GS

Custodians
Army-AT
Navy-OS
Air Force-99

Review Activities
Army-RV, EA, AR, MI
Navy-Sh
Air Force-11, 84

1.5 This standard does not purport to address all of the
safety concerns, if any, associated with its use. It is the
responsibility of the user of this standard to establish appro-
priate safety and health practices and determine the applica-
bility of regulatory requirements prior to use.

2. Referenced Documents

2.1 ASTM Standards: 3

A 108 Specification for Steel Bars, Carbon, Cold-Finished,
Standard Quality
A 276 Specification for Stainless Steel Bars and Shapes
A 295 Specification for High-Carbon Anti-Friction Bearing
Steels
A 976 Classification of Insulating Coatings by Composition,
Relative Insulating Ability and Application
B 21/B 21M Specification for Naval Brass Rod, Bar and
Shapes
B 124 Specification for Copper and Copper Alloy Forging
Rod, Bar, and Shapes
B 276 Test Method for Apparent Porosity in Cemented
Carbides
B 283 Specification for Copper and Copper Alloy Die
Forgings (Hot-Pressed)
D 3951 Practice for Commercial Packaging
E 18 Test Methods for Rockwell Hardness and Rockwell
Superficial Hardness of Metallic Materials
E 112 Test Methods for Determining Average Grain Size
E 140 Standard Hardness Conversion Tables for Metals
Relationship Among Brinell Hardness, Vickers Hardness,
Rockwell Hardness, Superficial Hardness, Knoop Hard-
ness, and Scleroscope Hardness
E 381 Test Methods for Detector calibration and Analysis of
Radionuclides
E 381 ASTM Adjuncts: Photographs for Rating Macro-
etched Steels (3 Plates)
E 384 Test Method for Microindentation Hardness of Ma-
terials
2.2 SAE Standards:
AMS 5618 Steel, Corrosion Resistant Bars, Wire and Forgings4
AMS 5630 Steel, Corrosion Resistant Bars, Wire and Forgings4
AMS 5749 Steel, Corrosion Resistant Bars, Wire and Forging and Tubing Premium Aircraft Quality for Bearing
Applications4

1 This specification is under the jurisdiction of ASTM Committee F34 on Rolling
Element Bearings and is the direct responsibility of Subcommittee F34.01 on
Rolling Element.

2 The Department of Defense, Standardization Directory, SD-1, may be found at:

3 For referenced ASTM standards, visit the ASTM website, www.astm.org, or
contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM
Standards volume information, refer to the standard’s Document Summary page on
the ASTM website.

4 Available from American Society of Mechanical Engineers (ASME), ASME
International Headquarters, Three Park Ave., New York, NY 10016-5990.
AMS 5880 Steel, Corrosion Resistant Bars, Wire and Forging for Bearing Applications
AMS 6440 Specification for Steel Bars, Forgings and Tubing 1.45Cr (0.98-1.10C) (SAE 52100) for Bearing Applications
AMS 6444 Specification for Steel Bars, Forgings and Tubing Premium Aircraft Quality for Bearing Applications
AMS 6490 Specification for Steel Bars, Forgings and Tubing
AMS 6491 Specification for Steel Bars, Forgings and Tubing 4.1Cr-4.2Mo-1.0V (0.80-0.85C) Premium Aircraft-Quality for Bearing Applications, Double Vacuum Melted

2.3 Federal Standards:
FED-STD-151 Metals, Test Methods
QQ-N-286 Specification for Nickel-Copper Aluminum Alloy, Wrought

2.4 Military Standards:
MIL-DTL-197 Specification for Bearings, Anti-Friction; Associated Parts and Subassemblies; Preparation for and Delivery
MIL-STD-129 Marking for Shipment and Storage
MS 3224 Balls, Bearing, Aircraft Quality Steel
MS 3226 Balls, Bearing, Grade 10, Aircraft Quality Steel
MS 19059 Balls, Bearing, Chrome Alloy Steel
MS 19060 Balls, Bearing, Corrosion Resistant Steel
MS 19061 Balls, Bearing, Carbon Steel
MS 19062 Balls, Bearing, Non-Ferrous Brass
MS 19063 Balls, Bearing, Bronze
MS 19064 Balls, Bearing, Nickel-Copper Alloy (K Monel)

2.5 ABMA Standard:
ABMA-STD-10 Metal Balls (Inactive Specification)

2.6 ANSI Standards:
B46.1 Surface Texture (Surface Roughness, Waviness and Lay)
B89.3.1 Sampling Procedures and Tables for Inspection by Attributes

2.7 NAS Standard:
NAS 410 Certification and Qualification of Nondestructive Test Personnel

2.8 ISO Standard:
ISO 3290 Rolling Bearings, Bearing Parts, Balls for Rolling Bearings

2.9 Automatic Identification Manufacturers (AIM):
AIM BC1 Uniform Symbology Specification Code

3. Terminology

3.1 Definitions of Terms Specific to This Standard:
3.1.1 ball gage deviation ($\Delta D$)—the diameter size of the balls, in inches.
3.1.2 basic diameter—the difference between the largest and smallest diameter measured on the same ball.
3.1.3 basic diameter tolerance—the maximum allowable deviation from the specified basic diameter for the indicated grade.
3.1.4 case depth—the thickness, measured radially from the surface of the hardened case to a point where carbon content or hardness becomes the same as the ball core.
3.1.5 deviation from spherical form ($\Delta Rw$)—the greatest radial distance in any radial plane between a sphere circumscribed around the ball surface and any point on the ball surface.
3.1.6 grade designation ($G$)—indicates the allowable out-of-roundness expressed in millionths of an inch.
3.1.7 lot—balls from a single production run of balls that are offered for delivery at one time that are of the same dimensions, made from metal material of the same type and composition, formed and fabricated under the same manufacturing processes.
3.1.8 marking increments—the standard unit steps to express the specific diameter.
3.1.9 nominal size ($Dw$)—the basic diameter, in inches, that is used for the purpose of general identification (for example, $\frac{1}{4}$, $\frac{1}{8}$, and so forth).
3.1.10 out-of-roundness—the difference between the largest and smallest diameter measured on the same ball.
3.1.11 passivation—a treatment for corrosion-resistant steel to eliminate corrosible surface impurities and provide a protective film.
3.1.12 specific diameter—the diameter marked on the unit container and expressed in the grade standard marking increment nearest to the average diameter of the balls in that container.
3.1.13 unit container—a container identified as containing balls from the same manufacturing lot of the same composition, grade, and basic diameter, and within the allowable diameter variation per unit container for the specified grade.

3.2 Acronyms:
3.2.1 VIMVAR—vacuum induction melt-vacuum arc remelt.

4. Classification

4.1 This specification covers balls of Compositions 1 through 14 (see Table 1), and Grades 3, 5, 10, 16, 24, 48, 100,

<table>
<thead>
<tr>
<th>TABLE 1 Classification of Balls</th>
</tr>
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<tbody>
<tr>
<td>Composition Number</td>
</tr>
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<td>-----------------------------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
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<tr>
<td>4</td>
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<td>12</td>
</tr>
<tr>
<td>13</td>
</tr>
<tr>
<td>14</td>
</tr>
</tbody>
</table>

5. Ordering Information

5.1 When ordering balls in accordance with this specification, specify the following:

5.1.1 ASTM designation number, including year of issue,
5.1.2 Applicable MS sheet standard number,
5.1.3 Diameter of balls, whether standard or nonstandard,
5.1.4 Composition number required (see Table 1),
5.1.5 Grade required (see ISO 3290 and ABMA-STD-10),
5.1.6 Whether a first article sample is required, and arrangements for testing and approval thereof,
5.1.7 Tests, test conditions, and sampling plans, if other than specified herein,
5.1.8 Quantity required,
5.1.9 Applicable levels of preservation and packing,
5.1.10 Special marking, if required, and
5.1.11 For Composition 13 balls (see Note 1):
      5.1.11.1 Traceability records for each ball, when required, including its corresponding heat treat lot, forging lot, consumable electrode remelt number, process lot number, and VIM-VAR heat of steel,
      5.1.11.2 Material identification records, when required,
      5.1.11.3 Eddy current inspection records, when required,
      and
      5.1.11.4 Ultrasonic inspection record for bar stock material, when required.

**Note 1—**The contract or purchase order should specify that the Composition 13 material, eddy current and ultrasonic inspection records are to be maintained for 15 years from the date of purchase order or contract completion, and that the records are to be available for delivery to the purchaser within 3 working days.

6. Materials and Manufacture

6.1 Composition 1—Composition 1 balls shall be manufactured from chrome alloy steel conforming to the chemical composition of UNS G51986 or UNS G52986 in accordance with AMS 6440 or AMS 6444 and Specification A 295. Chemical composition shall be tested in accordance with 11.2.

6.1.1 Material used in manufacture of Composition 1 balls shall conform to the inclusion rating specifications given in 7.6.

6.1.2 Material used in the manufacture of Composition 1 balls shall not exhibit defects as shown in Table 2 when tested in accordance with 11.15.1.

6.2 Composition 2—Composition 2 balls shall be manufactured from corrosion-resistant steel conforming to the chemical composition of UNS S44003, UNS S32900, UNS S42000, UNS S41000, UNS S42700, or UNS S44004 in accordance with Specification A 276 and AMS 5618, 5630, 5749 and 5880. Chemical composition shall be tested in accordance with 11.2.

6.2.1 Material used in the manufacture of Composition 2 balls shall conform to the inclusion rating specifications given in 7.6.

6.2.2 Material used in the manufacture of Composition 2 balls shall not exhibit defects as shown in Table 2 when tested in accordance with 11.15.1.

6.3 Composition 3—Composition 3 balls shall be manufactured from carbon steel conforming to the chemical composition of UNS G10080 through UNS G10220 in accordance with Specification A 108. Chemical composition shall be tested in accordance with 11.2.

6.3.1 The quality of the material used in the manufacture of Composition 3 balls shall have macrograph inspection in accordance with Test Methods E 381 and E 381 Adjuncts. Tests shall be in accordance with 11.15.2.

6.4 Composition 4—Composition 4 balls shall be manufactured from selected silicon molybdenum steel UNS T41902 of the through-hardened type as specified in Table 3. Chemical composition shall be tested in accordance with 11.2.

6.5 Composition 5—Composition 5 balls shall be manufactured from brass UNS C26000 as specified in Table 3. Chemical composition shall be tested in accordance with 11.2.

6.6 Composition 6—Composition 6 balls shall be manufactured from bronze conforming to the chemical composition of UNS C46400 (SAE CDA464) in accordance with Specifications B 283, B 124, B 21/B 21M, and B 21/B<sub>21M</sub> 21M. Chemical composition shall be tested in accordance with 11.2.

6.7 Composition 7—Composition 7 balls shall be manufactured from aluminum bronze UNS C62400 and UNS C6300 as specified in Table 3. Chemical composition shall be tested in accordance with 11.2.

---

**TABLE 2 Classification of Defects**

<table>
<thead>
<tr>
<th>Category</th>
<th>Defect</th>
<th>Testing Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>101</td>
<td>presence of more than one nonmetallic inclusions 1/8 to 1/4 in. (SI) long</td>
<td>measure</td>
</tr>
<tr>
<td>102</td>
<td>presence of one nonmetallic inclusion over 1/8 in. (SI) long</td>
<td>measure</td>
</tr>
<tr>
<td>103</td>
<td>presence of porosity, pipe or internal ruptures</td>
<td>visual</td>
</tr>
<tr>
<td>104</td>
<td>balls show evidence of contamination</td>
<td>visual</td>
</tr>
<tr>
<td>105</td>
<td>balls not free from decarburization, cracks, pits and indications of soft spots</td>
<td>visual</td>
</tr>
<tr>
<td>106</td>
<td>balls (bronze) not free from alloy segregation</td>
<td>visual</td>
</tr>
<tr>
<td>107</td>
<td>hardness of balls less than required limits</td>
<td>measure</td>
</tr>
<tr>
<td>Minor:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>packaging, packing and marking not in accordance with requirements</td>
<td>visual</td>
</tr>
</tbody>
</table>
6.8 Composition 8—Composition 8 balls shall be manufactured from beryllium copper as specified in Table 3. Chemical composition shall be tested in accordance with 11.2.

6.9 Composition 9—Composition 9 balls shall be manufactured from nickel-copper alloy (Monel) UNS N04400 as specified in Table 3. Chemical composition shall be tested in accordance with 11.2.

6.10 Composition 10—Composition 10 balls shall be manufactured from nickel-copper-aluminum alloy conforming to the chemical composition of UNS N05500 (K-Monel) in accordance with QQ-N-286. Chemical composition shall be tested in accordance with 11.2.

6.11 Composition 11—Composition 11 balls shall be manufactured from aluminum alloy UNS A92017 as specified in Table 3. Chemical composition shall be tested in accordance with 11.2.

6.12 Composition 12—Composition 12 balls shall be manufactured from tungsten carbide material as specified in Table 3. Chemical composition shall be tested in accordance with 11.2.

6.13 Composition 13—Composition 13 balls shall be manufactured from aircraft-quality steel conforming to the chemical composition of UNS T11350 or UNS T12001 in accordance with AMS 6490 or AMS 6491. Chemical composition shall be tested in accordance with 11.2.

6.13.1 Ultrasonic Inspection of Bar Stock—Bar and wire stock selected for the manufacture of Composition 13 balls shall be inspected using the ultrasonic inspection test method in Annex A1. Composition 13 bar and wire stock shall be tested 100%.

6.13.2 Material used in manufacture of Composition 13 balls shall conform to the inclusion rating specifications given in 7.6.

6.13.3 When a first article sample of Composition 13 ball material is required, chemical testing, fracture grain size, and inclusion rating are required in addition to other tests.

6.13.4 Material used in the manufacture of Composition 1 balls shall be macro-examined in accordance with 11.15.3.

6.14 Composition 14—Composition 14 balls shall be manufactured from corrosion-resistant unhardened steel conforming to the chemical composition of UNS S30200, UNS S30400, UNS S30500, UNS S31600, or UNS S43000 in accordance with Specification A 276. Chemical composition shall be tested in accordance with 11.2.

6.14.1 Material used in manufacture of Composition 14 balls shall conform to the inclusion rating specifications given in 7.6.

6.14.2 Material used in the manufacture of Composition 14 balls shall not exhibit defects as shown in Table 2 when tested in accordance with 11.15.1.

7. Other Requirements

7.1 Density—Density shall be as specified in Table 4 when tested in accordance with 11.3.

7.2 Hardness:

7.2.1 Hardness shall be as specified in Table 4 when tested in accordance with 11.4.

7.2.2 Composition 3 Hardness—Composition 3 balls shall have a minimum surface hardness of 60 HRC or equivalent.
when tested in accordance with 11.4. Composition 3 balls shall be case hardened to the depth specified in Table 5 when tested in accordance with 11.9.

7.3 Fracture Grain Size—Fracture grain size shall be in accordance with the material specification or as specified in Table 4, when tested in accordance with 11.5.

7.4 Porosity—Composition 12 balls shall not exceed the conditions for A02, B02, and C02 apparent porosity as given in Test Method B 276 when tested in accordance with 11.6.

7.5 Decarburization—Compositions 1, 2, 3, 4, and 13 balls shall not exhibit decarburization when tested in accordance with 11.8.

7.6 Inclusion Rating:

7.6.1 Compositions 1 and 2 Material Samples and Finished Balls—Compositions 1 and 2 material and finished balls shall not exceed the inclusion rating specified for billets to be used for wire and rods in the manufacture of balls and rollers as specified in Specification UNS T11350 or UNS T12001. Inclusion rating for finished Composition 13 balls shall be as specified in AMS 6490 or AMS 6491.

7.7 Retained Austenite—The retained austenite content of Composition 1 and 13 balls shall not exceed 3 % by volume, as determined using X-ray diffraction techniques, or other techniques as specified. The retained austenite content of Composition 2 balls shall not exceed 7 % by volume, as determined using X-ray diffraction techniques, or other techniques as specified.

7.8 Passivation—Composition 2 balls shall be passivated and shall not exhibit visible corrosion when tested in accordance with 11.10.

7.9 Eddy Current—Composition 13 balls shall pass the eddy current test given in 11.11, by meeting the requirements given in 11.11.6.

7.10 First Article—When specified in the purchase order or contract, a first article sample shall be provided. The sample item shall meet the requirements of Sections 7, 8, 9, and 14. The purchaser should include specific instructions in the purchase order or contract regarding arrangements for testing and approval of the first article sample.

8. Dimensions, Mass, and Permissible Variations

8.1 The basic diameter of the balls, whether standard or nonstandard, shall be as specified in the purchase order or contract. Tolerance limits for size (diameter) variations and spherical form variations shall be in accordance with Table 6 and Table 7 and the applicable MS sheet standards (see 2.4) for the respective metallic compositions and grades. Dimensions not within the tolerances specified on the applicable MS sheet standard and Table 6 and Table 7 shall be classified as a defect. Balls shall be tested for dimensional requirements in accordance with 11.13. ISO 3290 provides a listing of additional acceptable sizes.

### Table 4 Other Requirements

<table>
<thead>
<tr>
<th>Composition Number</th>
<th>Hardness&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Density, lbm/in.&lt;sup&gt;3&lt;/sup&gt;</th>
<th>Fracture Grain Size, max, see 7.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>58-67 HRC&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.283</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>58-65 HRC</td>
<td>0.277</td>
<td>7½</td>
</tr>
<tr>
<td>3</td>
<td>min 60 HRC&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.284</td>
<td>—</td>
</tr>
<tr>
<td>4</td>
<td>52-60 HRC</td>
<td>0.278</td>
<td>—</td>
</tr>
<tr>
<td>5</td>
<td>75-87 HRC</td>
<td>0.306</td>
<td>—</td>
</tr>
<tr>
<td>6</td>
<td>75-98 HRC or 15-20 HRC&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.304</td>
<td>—</td>
</tr>
<tr>
<td>7</td>
<td>15-20 HRC</td>
<td>0.273</td>
<td>—</td>
</tr>
<tr>
<td>8</td>
<td>min 38 HRC</td>
<td>0.300</td>
<td>—</td>
</tr>
<tr>
<td>9</td>
<td>85-95 HRC</td>
<td>0.318</td>
<td>—</td>
</tr>
<tr>
<td>10</td>
<td>min 27 HRC</td>
<td>0.306</td>
<td>—</td>
</tr>
<tr>
<td>11</td>
<td>54-72 HRC</td>
<td>0.101</td>
<td>—</td>
</tr>
<tr>
<td>12</td>
<td>87.5-90.4 HRA</td>
<td>0.539</td>
<td>—</td>
</tr>
<tr>
<td>13</td>
<td>61-64 HRC</td>
<td>0.279</td>
<td>8</td>
</tr>
<tr>
<td>14</td>
<td>25-39 HRC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 S43000</td>
<td>48-63 HRA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Hardness equivalent to those shown are also acceptable. See Standard Hardness Conversion Tables E 140.

<sup>b</sup>The balls within any unit container shall have a uniform hardness from ball to ball within three points HRC or equivalent.

<sup>c</sup>See 7.2.2.

<sup>d</sup>See 11.4.

### Table 5 Case Depth Requirements for Composition 3 Balls

<table>
<thead>
<tr>
<th>Nominal Size, in.</th>
<th>Allowable Ball Diameter Variation, millions of an inch, (V_{0.005})</th>
<th>Allowable Deviation from Spherical Form, millions of an inch, (\Delta R_w)</th>
</tr>
</thead>
<tbody>
<tr>
<td>At Least</td>
<td>But Not</td>
<td>Minimum Case Depth, in.</td>
</tr>
<tr>
<td>(1/8) (SI)</td>
<td>(1/8)</td>
<td>0.005</td>
</tr>
<tr>
<td>(5/32) (SI)</td>
<td>(5/32)</td>
<td>0.015</td>
</tr>
<tr>
<td>(3/32) (SI)</td>
<td>(3/32)</td>
<td>0.020</td>
</tr>
<tr>
<td>(1/32) (SI)</td>
<td>(1/32)</td>
<td>0.025</td>
</tr>
<tr>
<td>(7/64) (SI)</td>
<td>(7/64)</td>
<td>0.030</td>
</tr>
<tr>
<td>(1/16) (SI)</td>
<td>(1/16)</td>
<td>0.035</td>
</tr>
<tr>
<td>(5/64) (SI)</td>
<td>(5/64)</td>
<td>0.045</td>
</tr>
<tr>
<td>(3/32) (SI)</td>
<td>(3/32)</td>
<td>0.055</td>
</tr>
<tr>
<td>(1/16) (SI)</td>
<td>(1/16)</td>
<td>0.065</td>
</tr>
<tr>
<td>(5/64) (SI)</td>
<td>(5/64)</td>
<td>0.070</td>
</tr>
<tr>
<td>(3/32) (SI)</td>
<td>(3/32)</td>
<td>0.075</td>
</tr>
<tr>
<td>(1/16) (SI)</td>
<td>(1/16)</td>
<td>0.080</td>
</tr>
</tbody>
</table>

See 7.11.1.1 Presence of more than one nonmetallic inclusion between \(1/16\) and \(1/8\) in. long.

7.6.1.2 Presence of one nonmetallic inclusion over \(1/8\) in. long, or.

7.6.1.3 Presence of porosity, pipe, or internal ruptures.

7.6.2 Composition 13 Material Samples and Finished Balls—Inclusion rating for Composition 13 material samples shall not exceed the inclusion rating specified for billets to be used for wire and rods in the manufacture of balls and rollers as specified in Specification UNS T11350 or UNS T12001. Inclusion rating for finished Composition 13 balls shall be as specified in AMS 6490 or AMS 6491.

7.7 Retained Austenite—The retained austenite content of Composition 1 and 13 balls shall not exceed 3 % by volume, as determined using X-ray diffraction techniques, or other techniques as specified. The retained austenite content of Composition 2 balls shall not exceed 7 % by volume, as determined using X-ray diffraction techniques, or other techniques as specified.

7.8 Passivation—Composition 2 balls shall be passivated and shall not exhibit visible corrosion when tested in accordance with 11.10.

7.9 Eddy Current—Composition 13 balls shall pass the eddy current test given in 11.11, by meeting the requirements given in 11.11.6.

7.10 First Article—When specified in the purchase order or contract, a first article sample shall be provided. The sample item shall meet the requirements of Sections 7, 8, 9, and 14. The purchaser should include specific instructions in the purchase order or contract regarding arrangements for testing and approval of the first article sample.

8. Dimensions, Mass, and Permissible Variations

8.1 The basic diameter of the balls, whether standard or nonstandard, shall be as specified in the purchase order or contract. Tolerance limits for size (diameter) variations and spherical form variations shall be in accordance with Table 6 and Table 7 and the applicable MS sheet standards (see 2.4) for the respective metallic compositions and grades. Dimensions not within the tolerances specified on the applicable MS sheet standard and Table 6 and Table 7 shall be classified as a defect. Balls shall be tested for dimensional requirements in accordance with 11.13. ISO 3290 provides a listing of additional acceptable sizes.
9. Workmanship, Finish, and Appearance

9.1 Balls shall be free from decarburization, over tempering, and indication of soft spots.

9.2 All surfaces shall be free of scratches, nicks, pits, dents, seams, laps, tears, cracks, and corrosion when examined with an unaided eye. Balls having basic diameters of ¼ in. or less may be examined by magnification not exceeding 10 times.

9.3 Tolerance limits for scratches, pits, nicks, and dents on Composition 13 balls shall be in accordance with Table 8. Surface defects not within the tolerance of acceptable limits specified in Table 8 shall be cause for rejection.

9.4 Visual and Dimensional Testing—Balls shall meet the requirements of Table 9. Composition 13 balls shall be visually tested in accordance with 11.12.

9.5 Surface Roughness—The surface roughness of the balls shall not exceed the value specified in the applicable MS sheet standard (see 2.4) or Table 10 for the specified grade, when tested in accordance with 11.7.

9.6 Carbides—Carbides on the surfaces of finished Composition 13 balls shall not protrude more than 11 µin. above the surface of the ball, when tested in accordance with 11.14.

10. Sampling

10.1 Sampling for Visual and Dimensional Testing of Composition 1 through 12 and 14 Balls—Sampling shall be done in accordance with ANSI/ASQC Z1.4 or an equivalent sampling Table from “C = 0.” The unit of product for sampling purposes shall be one ball as applicable. Acceptance number shall be zero for all sample series unless otherwise specified.

10.2 Sampling for Examination of Composition 13 Balls:

10.2.1 Visual Examination—Composition 13 balls shall be inspected 100 %.

10.2.2 Dimensional Examination—Sampling for dimensional examination of Composition 13 balls shall be in accordance with ANSI/ASQC Z1.4 or an equivalent sampling Table from “C = 0.”

---

### TABLE 7 Tolerances by Grade for Lots of Balls

<table>
<thead>
<tr>
<th>Grade</th>
<th>Allowable Lot Diameter Variation, millionths of an inch, ( V_{DLW} )</th>
<th>Basic Diameter Tolerance, millionths of an inch</th>
<th>Allowable Ball Gage Deviation, millionths of an inch, ( \Delta s )</th>
<th>Container Marking Increment, millionths of an inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>5</td>
<td>±50</td>
<td>+30 -30</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>±50</td>
<td>+50 -40</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>±100</td>
<td>+50 -40</td>
<td>10</td>
</tr>
<tr>
<td>16</td>
<td>32</td>
<td>±100</td>
<td>+50 -40</td>
<td>10</td>
</tr>
<tr>
<td>24</td>
<td>48</td>
<td>±100</td>
<td>+100 -100</td>
<td>10</td>
</tr>
<tr>
<td>48</td>
<td>96</td>
<td>±200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>200</td>
<td>±500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>400</td>
<td>±1000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>1000</td>
<td>±2000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>2000</td>
<td>±5000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 8 Visual Inspection Limits for Composition 13 Balls

<table>
<thead>
<tr>
<th>Type of Defect</th>
<th>Acceptable Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pits</td>
<td>0.008 in. maximum dimension for single pit; maximum of 3 permitted in any ¼-in. diameter circle</td>
</tr>
<tr>
<td>Scratches</td>
<td>0.006 in. width; maximum of 1 per ball up to 50 % of circumference, any number up to 25 % of circumference; no cross-scratches permitted.</td>
</tr>
<tr>
<td>Nicks, dents, and indentations on balls of less than ¼-in. diameter</td>
<td>0.015 in. maximum dimension</td>
</tr>
<tr>
<td>Nicks, dents, and indentations on balls of ¼-in. diameter or larger</td>
<td>0.024 in. maximum dimension</td>
</tr>
</tbody>
</table>

### TABLE 9 Quality Conformance Inspection

<table>
<thead>
<tr>
<th>Test Inspection</th>
<th>Inspection Level</th>
<th>AQL (Defects Per 100 Units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual (see Table 2 and Table 8)</td>
<td>II</td>
<td>1.0</td>
</tr>
<tr>
<td>Major Defects (see Table 2)</td>
<td>II</td>
<td>6.5</td>
</tr>
<tr>
<td>Minor Defects (see Table 2)</td>
<td>II</td>
<td>6.5</td>
</tr>
<tr>
<td>Dimensional Examination: (see Tables 6 and 7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter tolerance per ball</td>
<td>S-1</td>
<td>2.5</td>
</tr>
<tr>
<td>Ball diameter variation</td>
<td>S-1</td>
<td>2.5</td>
</tr>
<tr>
<td>Measurement of deviation from spherical form</td>
<td>S-1</td>
<td>2.5</td>
</tr>
<tr>
<td>Tolerances by grade for lots of balls</td>
<td>S-1</td>
<td>2.5</td>
</tr>
<tr>
<td>Specific diameter marking</td>
<td>S-1</td>
<td>2.5</td>
</tr>
</tbody>
</table>

### TABLE 10 Surface Roughness by Grade for Individual Balls

<table>
<thead>
<tr>
<th>Grade</th>
<th>Maximum Surface Roughness Arithmetical Average, ( 10^{-6} ) in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.5</td>
</tr>
<tr>
<td>5</td>
<td>0.8</td>
</tr>
<tr>
<td>10</td>
<td>1.0</td>
</tr>
<tr>
<td>16</td>
<td>1.0</td>
</tr>
<tr>
<td>24</td>
<td>2.0</td>
</tr>
<tr>
<td>48</td>
<td>3.0</td>
</tr>
<tr>
<td>100</td>
<td>5.0</td>
</tr>
<tr>
<td>200</td>
<td>8.0</td>
</tr>
<tr>
<td>500</td>
<td>10.0</td>
</tr>
<tr>
<td>1000</td>
<td>20.0</td>
</tr>
</tbody>
</table>

---
11. Test Methods

11.1 Test Conditions—Unless otherwise specified, perform all tests under the following conditions:

11.1.1 Temperature—Room ambient.

11.1.2 Altitude—Normal ground.

11.2 Chemical Analysis:

11.2.1 Chemical analysis of each lot of material shall be tested in accordance with the appropriate material specification.

11.2.2 When specified in contract or purchase order, certification of chemical analysis (conformance) from the supplier of the specified material may be considered acceptable instead of actual testing by the manufacturer.

11.3 Density—Select samples of each composition in accordance with Section 10. Weigh the balls in air and divide the weight of each sample ball by the computed volume of the ball (cm³). The diameter used in computing the volume of the ball shall be determined in accordance with 11.13.1. Determine the weight of each sample ball to an accuracy of 2.205 × 10⁻⁶ lbm (0.001 g) or 10% of the weight, whichever is greater. Samples failing to comply with the density test requirements given in Table 4 shall be cause for lot rejection.

11.4 Ball Hardness—Select samples of each composition in accordance with Section 10. Test in accordance with Test Methods E 18, except for Composition 6. Test Composition 6 balls in accordance with MS 19063. Refer to tests made on parallel flats for hardness readings. If any of the samples fail to comply with the ball hardness requirement given in Table 4, the lot shall be rejected.

11.5 Fracture Grain Size—Select samples of Composition 1, 2, and 13 balls in accordance with Section 10. Fracture grain size shall be in accordance with the material specification. Examine in accordance with Test Methods E 112 or the test method appropriate to the material specification. Balls having fracture grain sizes for Compositions 1, 2, and 13 that are not in accordance with the requirements of the material specification shall be cause for rejection.

11.6 Porosity Test—Select Composition 12 balls in accordance with Section 10. Prepare and examine the balls in accordance with Test Method B 276 or other test method as approved by the purchaser. Sample units exceeding the conditions for A02, B02, and C02 apparent porosity shall be cause for lot rejection.

11.7 Surface Roughness—Select samples in accordance with Section 10. Test in accordance with ANSI B46.1. Sample units not complying with requirements of 9.5 shall be cause for lot rejection.

11.8 Decarburization—Select Compositions 1, 2, 3, 4, and 13 balls in accordance with Section 10. Examine balls for surface decarburization. Polish and microetch transverse sections through the center of sample balls, and examine at a magnification of 100 diameters. Test specimens exhibiting surface decarburization shall be cause for lot rejection.

11.9 Case Depth—Select Composition 3 balls in accordance with Section 10. Polish and microetch transverse sections through the center of sample balls, and examine using appropriate measuring devices or instruments. Test specimens not complying with case depth requirements shown in Table 5 shall be cause for lot rejection. See Test Method E 384.

11.10 Passivation—Select Composition 2 balls in accordance with Section 10. Passivate in accordance with AMS-QQ-P-35 or Classification A 976. Test for acceptance in accordance with the appropriate test method in the passivation specification. Use the following or equivalent test method. Immerse samples in distilled water at 100 ± 5°F for 1 h, and then air dry at 100 ± 5°F for 1 h. Repeat this cycle for a total of 24 h. At the end of the 24-h test period, examine the sample balls for surface corrosion, using a 10 X power magnification. Samples exhibiting visible corrosion shall be cause for lot rejection.

11.11 Eddy Current:

11.11.1 Personnel—Personnel performing the eddy current testing shall meet the requirements of NAS 410.

11.11.2 Calibration Standard—The calibration standard shall be a ball of the same material, heat treat condition and grade as the ball being tested. The diameter of the calibration standard shall be the same as the nominal diameter of the ball being tested. The calibration standard shall have an electrical discharge machining (EDM) notch on its surface that is between 0.030 and 0.032 in. by 0.004 in. maximum wide and 0.004 in. maximum deep. Measure and record notch dimensions.

11.11.3 Residual Magnetism—Check the calibration standard and balls for residual magnetism prior to testing. All parts shall have less than 0.50 gauss before testing.

11.11.4 Scanning Coverage—Scanning increments shall be no greater than the diameter of the coil being used for the test. Continuously scan the entire periphery of the ball surface. Use the same scanning speeds for testing and calibration. Verify full scanning of parts being tested at the beginning and at the end of each inspection lot. If fixturing requires adjustment, reinspect all parts inspected since previous check.

11.11.5 Signal and Noise—Set up test equipment so that calibration standards produce a signal of 50% of the screen height. Do not change sensitivity adjustments during testing to compensate for drift within the machine; do not adjust sensitivity greater than ± 10% from the previously established calibration. Verify meter deflection on the calibration standard at the beginning and at the end of each inspection lot.

11.11.6 Ball Rejection—Calibration standards trip the reject signal; segregate them from acceptable balls. Reject any production balls that signal equal to or greater than the calibration level of the EDM notch in the calibration standards. Segregate any rejected balls.

11.11.7 Processing After Eddy Current Testing—Reinspect any balls that are processed in any way following eddy current testing.

11.12 Visual Testing for Composition 13 Balls—Sample balls in accordance with 10.2. Inspect balls for defects using the unaided eye (unless magnification is specified). Use a...
radius scribe as the initial determination of acceptability for defects. Use a 0.030-in. radius on balls ½ in. diameter and larger. Use a 0.020-in. radius scribe on balls less than ½ in. diameter. If the defect is detectable with the scribe, or if the acceptance criteria of Table 7 are not met, the ball shall be rejected.

11.13 Dimensional Testing:

11.13.1 Diameter Tolerance Per Ball and Ball and Lot Diameter Variation—Sample in accordance with Section 10. Take a minimum of 10 measurements in random orientations of each sample ball. If samples do not comply with out-of-roundness requirements, the lot shall be rejected. See Tables 6 and 7.

11.13.2 Measurement of Deviation from Spherical Form—Sample in accordance with Section 10. Test in accordance with Annex A10. If sample balls do not satisfy the requirements of Table 6, the lot shall be rejected.

11.13.3 Tolerances by Grade for Lots of Balls—Sample lots of balls in accordance with Section 10. Take a minimum of 10 measurements in random orientations of each sample ball. If sample packages do not comply with the requirements of 8.1, they shall be rejected.

11.13.4 Specific Diameter Marking—Sample in accordance with Section 10. Take a minimum of 10 measurements in random orientations of each sample ball. Marking shall be within one marking increment of the average diameter of the balls in the unit container (see Table 7). Any unit package that does not comply with these requirements shall be rejected.

11.14 Carbides on Finished Composition 13 Balls—Inspect five ball sample from each lap load of finished Composition 13 balls at 250 times or greater magnification. Select 3 random fields per ball, approximately 120° apart. Measure raised carbides using an optical interferometer or other suitable device. If a ball contains a raised carbide with a height above the ball surface in excess of 11 µin., reject the lap load.

11.15 Macro-Examinations:

11.15.1 Compositions 1 and 2 Balls—Take specimens that are ⅛ in. thick (and representative of the cross section of 4-in. square rolled billets) for forged sections that are 4-in. square (used for forging and re-rolling into coils, tube rounds, and bars) from the top and bottom areas of the first, middle, and last of usable ingots of a heat. Normalize, anneal, harden, and fracture these specimens. Ensure that the specimens do not have external indentations sufficient to guide the fracture during the examination. Examine fractured surfaces for the defects listed in Table 2.

11.15.2 Composition 3 Balls—Select samples for examination from the billets for the wire or rods used in the manufacture of the balls, in accordance with Method 321 of FED-STD-151. Conduct macro-examination of each heat of steel in accordance with Test Methods E 381. The quality of steel as indicated by the results of the macro-examination shall be as agreed upon between the producer and the vendor. Defects exhibiting profiles of an unacceptable condition in Plates I, II, and III in Test Methods E 381 Adjuncts shall not be considered acceptable. When specified in the purchase order or contract, a certified material analysis report (certificate of conformance) submitted by the mill supplier is an acceptable alternate to the macro-examination of the material.

11.15.3 Composition 13 balls—Perform macro-examination in accordance with AMS 6490 and AMS 6491.

12. Inspection

12.1 Inspection of the balls shall be in accordance with the requirements of Sections 6 through 11 and Table 1 through Table 10 and as agreed upon between the purchaser and the supplier. The supplier is responsible for performance of all testing and inspection requirements.

13. Certification

13.1 Unless otherwise specified in the contract or purchase order, the supplier is responsible for performance of all testing and inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the supplier may use his own or any other facility suitable for the performance of such tests or inspections, or both, unless disapproved by the purchaser.

13.2 When specified in the contract or purchase order, certificates of quality (conformance) supplied by the manufacturer of the metal balls may be furnished instead of actual performance of such testing by the supplier, provided that lot identity has been maintained and can be demonstrated to the purchaser. The certificate shall include the name of the purchaser, contract number, name of the manufacturer or supplier, NSN, item identification, name of the material, lot number, lot size, sample size, date of testing, test method, individual test results, and the specification requirements.

14. Packaging and Package Marking

14.1 Military Packing—When MIL-DTL-197 is called out in the contract or purchase order, the balls shall be cleaned, dried, preserved, and packaged in accordance with Level A Method of Preservation and Level C Method of Packaging.

14.2 Commercial Packing—When commercial industrial preservation and packaging are called out in the contract or purchase order, the balls shall be cleaned, dried, preserved and packaged in accordance with Practice D 3951.

14.3 Marking:

14.3.1 Military—In addition to any special or other identification marking required by the contract or purchase order, each unit pack, intermediate and exterior container shall be marked in accordance with MIL-STD-129 and AIM BC1 for bar code requirements.

14.3.2 Industrial—Industrial marking shall be in accordance with Practice D 3951.

15. Keywords

15.1 ball bearing; ball valve; bearing; bearing accessories; bearing rolling elements
A1. TEST METHOD FOR ULTRASONIC TESTING OF COMPOSITION 13 BAR STOCK

A1.1 Scope
A1.1.1 This annex covers the procedure for ultrasonic testing of Composition 13 bar stock selected for the manufacture of bearing balls.

A1.2 Significance and Use
A1.2.1 Balls may be used in engine and gearbox bearings on rotary and fixed winged aircraft.

A1.3 Personnel
A1.3.1 Personnel performing the inspection shall meet the requirements of NAS 410.

A1.4 Sampling
A1.4.1 Sampling shall be done in accordance with 10.3.

A1.5 Calibration and Standardization
A1.5.1 Calibration Standard—Reference pieces for calibration shall be of the same material, metal travel distance, surface finish, and ultrasonic response as the bar stock being tested.

A1.5.2 Reference Test Pieces:
A1.5.2.1 For Bar Stock 5/8 to 1 1/2 in.-Diameter—The reference test piece shall be a bar of at least 3 ft. in length. For near zone testing, metal travel shall be four-tenth the diameter and nine-tenth the diameter of the test piece to flat bottom holes (FBHs) 0.020 in. in diameter. For far zone testing, metal travel shall be six-tenth the diameter and one-tenth the diameter of the test piece to FBHs 0.020 in. in diameter. For angle scanning, a shear notch 0.0070 ± 0.0005 in. deep, axially oriented, and located at least 8 in. from the end of the bar shall be used. The notch shall be produced from a 1-in. end mill with a 0.0002-in. maximum radius. Ultrasonic reflectors shall be spaced a minimum of 2 in. apart.

A1.5.2.2 For Bar Stock 1/2 to 5/8 in.-Diameter—The reference test piece shall have all the requirements of A1.5.1 and A1.5.2.1, except for the following: for near zone testing, metal travel of nine-tenth the test piece diameter shall be replaced with metal travel to a 0.020-in. diameter FBH of 0.062-in. depth. For far zone testing, metal travel of one-tenth the test piece diameter shall be replaced with metal travel of 0.062-in. to a 0.020-in. FBH.

A1.5.2.3 For Bar Stock Less Than 1/2-in. Diameter—For bar stock less than 0.500 in. diameter, only one FBH providing one half diameter travel is required in addition to the shear notch of A1.5.2.1.

A1.6 Procedure
A1.6.1 Longitudinal Scan—While maintaining the correct water path, obtain a 2-in. signal from the highest attenuated 2-in. FBH. Adjust the sensitivity and distance amplitude control to bring near and far FBHs within ±10 % of a 2-in. amplitude indication. Establish compatibility between the reference block and the material to be tested by comparing the first unsaturated back reflection from the block with the corresponding back reflection from the material to be tested. Gain shall be set to give an 80 % of screen signal from the FBH with a depth of six-tenth the diameter of the test piece. Check the compatibility in at least three well-separated areas on the material to be tested. Set the gate width for near zone testing to include response from FBH with a depth of one-tenth (or 0.062-in. holes) and a six-tenth test piece diameter. Set the gate width for far zone testing to include the response from FBH with a depth of a four-tenth and a nine-tenth test piece diameter. Set the alarm sensitivity to ensure 100 % of a 0.020-in. diameter FBH inspection level. Use a maximum surface scanning speed of 15 in./s. Hash or ultrasonic noise exceeding 50 % of the response from a FBH is not acceptable.

A1.6.2 Loss of Backface—Set the instrument so the first backface reflection from the full round reference block is 80 % of the screen saturation. Gate the first backface reflection and set the alarm at 50 % or less of loss in the backface signal. Observe the scanning speed, acceptable noise level, and indexing requirement listed under the longitudinal scan. Inspect and evaluate the loss of backface areas.

A1.6.3 Angle Scan Test—Position the transducer over the angle reference notch area for maximum response. Rotate the reference standard so the center of the standard block and the notch are on a horizontal plane. Adjust the gain to obtain a 2-in. signal and adjust the flaw alarm for a 1-in. signal. Set the gate width to include the area at which the signal from the reference notch is detected. Ensure that the scan speed, acceptable noise level, and indexing are as established under the longitudinal scan.

A1.7 Interpretation of Results
A1.7.1 Longitudinal Scan—Discontinuities in excess of the response from a 0.020-in. diameter FBH at the estimated discontinuity depth shall not be acceptable.

A1.7.2 Loss of Back Reflection—Any loss of back reflection in excess of 50 % of full saturation of the screen shall be considered unacceptable with the instrument set so the first back reflection from the correct test block is at 80 % of the screen adjusted for nonlinearity.

A1.7.3 Angle Scan—Discontinuities in excess of 50 % of the response from the axially oriented notch shall not be acceptable.

A1.8 Precision and Bias
A1.8.1 All bar stock for Composition 13 balls must meet all of the requirements for UT testing as set forth in this specification. Material shall be 100 % inspected.
A2. MS19062 BALLS, BEARING, NONFERROUS BRASS

A2.1 Requirements

A2.1.1 Material—Nonferrous brass conforming to chemical composition of UNS C26000. Balls shall be manufactured from selected brass free from alloy segregation, and shall be free from cracks when examined visually without magnification.

A2.1.2 Hardness—Surface hardness of Rockwell Rb 75-87 or equivalent measured on parallel flats.

A2.1.3 Surface Roughness—Not to exceed the maximum roughness height value (AA) of 8 µin., interpreted in accordance with ANSI B46.1.

A2.1.4 Material Density—306 lb/in.³

A2.1.5 Part Number:

A2.1.5.1 The MS part number consists of the MS number, plus the dash number. Example: MS 19062-20001 is the part number for a Grade 200 nonferrous brass-bearing ball with a basic diameter of 0.062500 in.

A2.1.5.2 Dash numbers, formerly designated -1 through -19, have been redesignated -20001 through -20019.

A2.1.6 Dimensions—All dimensions are in inches, unless otherwise specified. Column headings in tolerance tables are defined in ABMA-STD-10.

A2.2 Notes

A2.2.1 Referenced documents shall be of the issue in effect on date of invitation for bids.

A2.2.2 For design feature purposes, this specification takes precedence over procurement documents referenced herein.
### TABLE A2.1 Dash Numbers Basic Diameter

<table>
<thead>
<tr>
<th>Nominal Ball Diameter</th>
<th>Basic Diameter ØD</th>
<th>Grade 200 Dash No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/16</td>
<td>0.062500</td>
<td>20001</td>
</tr>
<tr>
<td>5/32</td>
<td>0.093750</td>
<td>20002</td>
</tr>
<tr>
<td>1/8</td>
<td>0.125000</td>
<td>20003</td>
</tr>
<tr>
<td>7/32</td>
<td>0.156250</td>
<td>20004</td>
</tr>
<tr>
<td>1/4</td>
<td>0.187500</td>
<td>20005</td>
</tr>
<tr>
<td>9/32</td>
<td>0.218750</td>
<td>20006</td>
</tr>
<tr>
<td>1/8</td>
<td>0.250000</td>
<td>20007</td>
</tr>
<tr>
<td>11/32</td>
<td>0.281250</td>
<td>20008</td>
</tr>
<tr>
<td>5/16</td>
<td>0.312500</td>
<td>20009</td>
</tr>
<tr>
<td>13/32</td>
<td>0.343750</td>
<td>20100</td>
</tr>
<tr>
<td>3/8</td>
<td>0.375000</td>
<td>20101</td>
</tr>
<tr>
<td>15/32</td>
<td>0.406250</td>
<td>20102</td>
</tr>
<tr>
<td>7/16</td>
<td>0.437500</td>
<td>20103</td>
</tr>
<tr>
<td>17/32</td>
<td>0.468750</td>
<td>20104</td>
</tr>
<tr>
<td>19/32</td>
<td>0.500000</td>
<td>20105</td>
</tr>
<tr>
<td>9/16</td>
<td>0.531250</td>
<td>20106</td>
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<tr>
<td>5/8</td>
<td>0.562500</td>
<td>20107</td>
</tr>
<tr>
<td>11/16</td>
<td>0.609375</td>
<td>20108</td>
</tr>
<tr>
<td>3/4</td>
<td>0.656250</td>
<td>20109</td>
</tr>
<tr>
<td>19/32</td>
<td>0.698750</td>
<td>20110</td>
</tr>
<tr>
<td>7/8</td>
<td>0.750000</td>
<td>20111</td>
</tr>
</tbody>
</table>

### TABLE A2.2 Tolerance by Grade for Individual Balls

(Tolerance in millionths of an inch)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Allowable Ball Diameter Variation, ( V_D )</th>
<th>Allowable Deviation from Spherical Form, ( W )</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
</tbody>
</table>

### TABLE A2.3 Tolerances by Grade for Lots of Balls

(Tolerance in millionths of an inch)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Allowable Lot Diameter Variation</th>
<th>Basic Diameter Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>400</td>
<td>±1000</td>
</tr>
</tbody>
</table>
A3. Requirements

A3.1.1 Material—Aircraft quality steel conforming to the chemical composition of UNS T11350 in accordance with AMS 6490 and AMS 6491 and as specified in procurement document.

A3.1.2 Hardness—Shall be 61-64 HRC or equivalent.

A3.1.3 Surface Roughness—Tolerance limits for surface roughness as specified in Table A3.2, and in accordance with ANS B46.1.

A3.1.4 Material Density—Shall be 0.279 lb/in.\(^3\)

A3.1.5 Part Number—Consists of the basic MS number followed by a dash number from Table A3.1 (see Fig. A3.2 for example).

A3.2 Notes

A3.2.1 All dimensions are in inches. Column headings in tolerance tables are in accordance with ABMA-STD-10.

A3.2.2 Grade 10 balls are preferred in most military applications.

A3.2.3 In the event of a conflict between the test of this specification and the references cited herein, the text of this specification shall take precedence.

A3.2.4 Referenced government (or nongovernment) documents of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DOISS) specified in the solicitation form a part of this specification to the extent specified herein.

Example: MS3224-0301

Dash number

Basic MS number

Note: MS3224-0301 indicates a Grade 3 bearing ball of aircraft-quality steel with a basic diameter of 0.03125 in.
### TABLE A3.1 Dash Numbers and Dimensions

<table>
<thead>
<tr>
<th>Nominal Ball Diameter</th>
<th>Basic Diameter</th>
<th>Grade</th>
<th>3</th>
<th>5</th>
<th>10⁶</th>
<th>16</th>
<th>24</th>
<th>48</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/16</td>
<td>0.015625</td>
<td>0.015625</td>
<td>0.015625</td>
<td>0.015625</td>
<td>0.015625</td>
<td>0.015625</td>
<td>0.015625</td>
<td>0.015625</td>
</tr>
<tr>
<td>3/64</td>
<td>0.046875</td>
<td>0.046875</td>
<td>0.046875</td>
<td>0.046875</td>
<td>0.046875</td>
<td>0.046875</td>
<td>0.046875</td>
<td>0.046875</td>
</tr>
<tr>
<td>1/8</td>
<td>0.062500</td>
<td>0.062500</td>
<td>0.062500</td>
<td>0.062500</td>
<td>0.062500</td>
<td>0.062500</td>
<td>0.062500</td>
<td>0.062500</td>
</tr>
<tr>
<td>5/64</td>
<td>0.078125</td>
<td>0.078125</td>
<td>0.078125</td>
<td>0.078125</td>
<td>0.078125</td>
<td>0.078125</td>
<td>0.078125</td>
<td>0.078125</td>
</tr>
<tr>
<td>3/32</td>
<td>0.093750</td>
<td>0.093750</td>
<td>0.093750</td>
<td>0.093750</td>
<td>0.093750</td>
<td>0.093750</td>
<td>0.093750</td>
<td>0.093750</td>
</tr>
<tr>
<td>7/64</td>
<td>0.109375</td>
<td>0.109375</td>
<td>0.109375</td>
<td>0.109375</td>
<td>0.109375</td>
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<td>0.109375</td>
<td>0.109375</td>
</tr>
<tr>
<td>1/4</td>
<td>0.125000</td>
<td>0.125000</td>
<td>0.125000</td>
<td>0.125000</td>
<td>0.125000</td>
<td>0.125000</td>
<td>0.125000</td>
<td>0.125000</td>
</tr>
<tr>
<td>11/64</td>
<td>0.131250</td>
<td>0.131250</td>
<td>0.131250</td>
<td>0.131250</td>
<td>0.131250</td>
<td>0.131250</td>
<td>0.131250</td>
<td>0.131250</td>
</tr>
<tr>
<td>3/16</td>
<td>0.156250</td>
<td>0.156250</td>
<td>0.156250</td>
<td>0.156250</td>
<td>0.156250</td>
<td>0.156250</td>
<td>0.156250</td>
<td>0.156250</td>
</tr>
</tbody>
</table>

A See Table A3.3 for tolerances.
B See A3.2.2.

### TABLE A3.2 Tolerance by Grade for Individual Balls (Tolerance in millionths of an inch)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Allowable Ball Diameter Variation, V_D</th>
<th>Allowable Deviation from Spherical Form, W</th>
<th>Maximum Surface Roughness (Arithmetical Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
<td>0.5</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
<td>0.8</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>10</td>
<td>1.0</td>
</tr>
<tr>
<td>16</td>
<td>16</td>
<td>16</td>
<td>1.0</td>
</tr>
<tr>
<td>24</td>
<td>24</td>
<td>24</td>
<td>2.0</td>
</tr>
<tr>
<td>48</td>
<td>48</td>
<td>48</td>
<td>3.0</td>
</tr>
</tbody>
</table>

See Table A3.3 for tolerances.
See A3.2.2.
A4. MS3226 BALLS, BEARING, GRADE 10, AIRCRAFT QUALITY STEEL

A4.1 Requirements

A4.1.1 Material—Aircraft-quality steel, chemical composition UNS T11350 in accordance with AMS 6490 and AMS 6491 and as specified as Composition 13 in procurement document.

A4.1.2 Hardness—As specified in procurement document.

A4.1.3 Surface Roughness—Tolerance limits for surface roughness as specified in Table A4.2 and in accordance with ANSI B46.1.

A4.1.4 Material Density—Material density shall be 0.279 lb/in.3

A4.1.5 Ball Grade—All balls shall be Grade 10 as defined by ABMA-STD-10.

A4.1.6 Part Number—The part number shall consist of this MS number followed by a dash and the basic diameter required as selected from Table A4.1 (see Fig. A4.2 for example).

A4.2 Notes

A4.2.1 All dimensions are in inches. Column headings in tolerance tables are in accordance with ABMA-STD-10.

A4.2.2 Some MS3226 part numbers supersede some MS3224 part numbers (see Table A4.4). MS3224 balls cannot be used as replacements for MS3226 balls.

A4.2.3 In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

A4.2.4 Referenced government (or nongovernment) documents of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DODISS) specified in the solicitation form a part of this specification to the extent specified herein.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Allowable Lot Diameter Variation</th>
<th>Basic Diameter Tolerance</th>
<th>Allowable Ball Gage Deviation</th>
<th>Container Marking Increment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>±30</td>
<td>+30  -30</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>±50</td>
<td>+50  -40</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>±100</td>
<td>+50  -40</td>
<td>10</td>
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<td>32</td>
<td>±100</td>
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<tr>
<td>24</td>
<td>48</td>
<td>±100</td>
<td>+100 -100</td>
<td>10</td>
</tr>
<tr>
<td>48</td>
<td>96</td>
<td>±200</td>
<td>A</td>
<td>50</td>
</tr>
</tbody>
</table>

*Not applicable.

NOTE—MS3226-0.9992 indicates a Grade 10 bearing ball of aircraft-quality steel with a basic diameter of 0.9992 in.

FIG. A4.1

FIG. A4.2 Example
<table>
<thead>
<tr>
<th>Nominal Bell Diameter</th>
<th>Basic Diameter, $D_B$</th>
<th>Nominal Ball Diameter</th>
<th>Basic Diameter, $D_B$</th>
<th>Nominal Ball Diameter</th>
<th>Basic Diameter, $D_B$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{1}{8}$</td>
<td>0.1240</td>
<td>$\frac{7}{32}$</td>
<td>0.2178</td>
<td>$\frac{5}{16}$</td>
<td>0.3115</td>
</tr>
<tr>
<td></td>
<td>0.1242</td>
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<td>0.2180</td>
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<td>0.3117</td>
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<td></td>
<td>0.1244</td>
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<td>0.2182</td>
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<td>0.3119</td>
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<td>0.1252</td>
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<td>0.3127</td>
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<tr>
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#### TABLE A4.2 Tolerance for Individual Balls (Tolerance in millionths of an inch)

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1.0633 1.2508 1.4383
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1.1246 1.3121 1.5006
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### TABLE A4.3 Tolerance for Lots of Balls (Tolerance in millionths of an inch)

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*See A4.2.2.*
A5. MS19059 BALLS, BEARING, CHROME ALLOY STEEL

A5.1 Requirements

A5.1.1 Material—Chrome alloy steel, conforming to the chemical composition of UNS G51986 in accordance with AMS 6444 or ANS G52986 in accordance with AMS 6440, and as specified in procurement document.

A5.1.2 Hardness—Shall be 60-67 HRC or equivalent.

A5.1.3 Surface Roughness—Tolerance limits for surface roughness as specified in Table A5.2, and in accordance with ANSI B46.1.

A5.1.4 Material Density—Shall be 0.283 lb/in.³

A5.1.5 Part Number—Consists of the basic MS number followed by a dash number from Table A5.1 (see Fig. A5.2 for example).

A5.2 Notes

A5.2.1 All dimensions are in inches. Column headings in tolerance tables are in accordance with ABMA-STD-10.

A5.2.2 In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

A5.2.3 Referenced government (or nongovernment) documents of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DODISS) specified in the solicitation form a part of this specification to the extent specified herein.

Note—MS19059-504 indicates a Grade 5 bearing ball of chrome alloy steel with a basic diameter of 0.062500 in.

FIG. A5.1

FIG. A5.2 Example
### Table A5.1 Dash Numbers and Dimensions

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* See Table A5.3 for tolerances.
### TABLE A5.2 Tolerance by Grade for Individual Balls (Tolerance in millionths of an inch)

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### TABLE A5.3 Tolerances by Grade for Lots (Tolerance in millionths of an inch)

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A6. MS19060 BALLS, BEARING, CORROSION-RESISTANT STEEL

A6.1 Requirements

A6.1.1 Material—Corrosion-resistant steel, conforming to the chemical composition of UNS S44003 or UNS S44004 in accordance with Specification A 276 and as specified in procurement document.

A6.1.2 Hardness—Shall be 58-65 HRC or equivalent.

A6.1.3 Surface Roughness—Tolerance limits for surface roughness as specified in Table A6.2, and in accordance with ANSI B46.1.

A6.1.4 Material Density—Shall be 0.277 lb/in.³

A6.1.5 Part Number—Consists of the basic MS number followed by a dash number from Table A6.1 (see Fig. A6.2 for example).

A6.2 Notes

A6.2.1 All dimensions are in inches. Column headings in tolerance tables are in accordance with ABMA-STD-10.

A6.2.2 In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

A6.2.3 Referenced government (or nongovernment) documents of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DODISS) specified in the solicitation form a part of this specification to the extent specified herein.

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Note—MS19060-504 indicates a Grade 5 bearing ball of corrosion-resistant steel with a basic diameter of 0.062500 in.

FIG. A6.1

EXAMPLE: MS19060-504

DASH NUMBER

BASIC MS NUMBER

FIG. A6.2 Example
### TABLE A6.1 Dash Numbers and Dimensions

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[^a]: See Table A6.3 for tolerances.
### TABLE A6.2 Tolerance by Grade for Individual Balls (Tolerance in millionths of an inch)

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<th>Allowable Ball Diameter Variation, (V_D)</th>
<th>Allowable Deviation from Spherical Form, (W)</th>
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### TABLE A6.3 Tolerances by Grade for Lots (Tolerance in millionths of an inch)

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<th>Container Marking Increment</th>
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\(^A\) Not applicable.
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A7. MS19061 BALLS, BEARING, CARBON STEEL

A7.1 Requirements

A7.1.1 Material—Carbon steel conforming to the chemical composition of UNS G10080 through UNS 10220 in accordance with Specification A 108 and as specified in procurement document.

A7.1.2 Hardness—Shall be 60 HRC or equivalent. Hardness readings taken on spherical surface are subject to ball hardness corrections for curvatures specified in ABMA-STD-10.

A7.1.3 Surface Roughness—Tolerance limits for surface roughness as specified in Table A7.2, and in accordance with ANSI B46.1.

A7.1.4 Material Density—Shall be 0.284 lb/in.³

A7.1.5 Part Number—Consists of the basic MS number followed by a dash number from Table A7.1 (see Fig. A7.2 for example).

A7.2 Notes

A7.2.1 All dimensions are in inches. Column headings in tolerance tables are in accordance with ABMA-STD-10.

A7.2.2 Dash numbers 20001 through 20021 were formerly dash 1 through 21.

A7.2.3 In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

A7.2.4 Referenced government (or nongovernment) documents of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DODISS) specified in the solicitation form a part of this specification to the extent specified herein.

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</table>

⁴ Even numbers only.

Example: MS19061 - 10001

Dash Number

Basic MS Number

Note—MS 19061-10001 indicates a Grade 100 bearing ball of carbon steel with a diameter of 0.062500 in.

FIG. A7.1

FIG. A7.2 Example
### Table A7.1 Dash Numbers and Dimensions

<table>
<thead>
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<th>ØD Nominal Ball Diameter</th>
<th>Basic Diameter&lt;sup&gt;A&lt;/sup&gt;</th>
<th>Grade</th>
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<sup>A</sup> See Table A7.3 for tolerances.

<sup>B</sup> See A7.2.2.

### Table A7.2 Tolerance by Grade for Individual Balls (Tolerance in millionths of an inch)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Allowable Ball Diameter Variation, $V_D$</th>
<th>Allowable Deviation from Spherical Form, $W$</th>
<th>Maximum Surface Roughness (Arithmetical Average)</th>
</tr>
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<tbody>
<tr>
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</table>

<sup>▲</sup> Not applicable.

### Table A7.3 Tolerances by Grade for Lots of Balls (Tolerance in millionths of an inch)

<table>
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<tr>
<th>Grade</th>
<th>Allowable Lot Diameter Variation</th>
<th>Basic Diameter Tolerance</th>
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A8.1 Requirements

A8.1.1 Material—Bronze conforming to the chemical composition of UNS C46400 (CDA 464) in accordance with Specifications B 21/B 21M, B 124, and B 283 and as specified in procurement document.

A8.1.2 Hardness—Shall be as follows:

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<th>Basic Diameter</th>
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<td>0.875000 to 1.250000</td>
<td>HRC15-20</td>
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A8.1.3 Surface Roughness—Tolerance limits for surface roughness as specified in Table A8.2, and in accordance with ANSI B46.1.

A8.1.4 Material Density—Shall be 0.304 lb/in.³

A8.1.5 Preferred Balls—Balls with basic diameter of 0.750000 and smaller are preferred. Balls with basic diameter greater than 0.750000 are inactive for new design.

A8.1.6 Part Number—The part number shall consist of the basic MS number followed by a dash number from Table A8.1 (see Fig. A8.2 for example).

A8.2 Notes

A8.2.1 All dimensions are in inches. Column headings in tolerance tables are in accordance with ABMA-STD-10.

A8.2.2 Dash numbers 20001 through 20023 were formerly dash 1 through 23.

A8.2.3 In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

A8.2.4 Referenced government (or nongovernment) documents of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DODISS) specified in the solicitation form a part of this specification to the extent specified herein.
TABLE A8.1 Dash Numbers and Dimensions

<table>
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<th>ØD Nominal Ball Diameter</th>
<th>Basic Diameter</th>
<th>Grade</th>
<th>200</th>
<th>500</th>
<th>1000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>10019</td>
</tr>
<tr>
<td>7/8</td>
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<td></td>
<td>2020</td>
<td>5020</td>
<td>10020</td>
</tr>
<tr>
<td>1/2</td>
<td>1.250000</td>
<td></td>
<td>2021</td>
<td>5021</td>
<td>10021</td>
</tr>
</tbody>
</table>

Table A8.1 Notes:
- A See Table A8.3 for tolerances.
- B See A8.2.2
- C See A8.1.5

TABLE A8.2 Tolerance by Grade for Individual Balls (Tolerance in millionths of an inch)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Allowable Ball Diameter Variation, Vd</th>
<th>Allowable Deviation from Spherical Form, W</th>
<th>Maximum Surface Roughness (Arithmetical Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>200</td>
<td>200</td>
<td>8</td>
</tr>
<tr>
<td>500</td>
<td>500</td>
<td>500</td>
<td>8</td>
</tr>
<tr>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A</td>
</tr>
</tbody>
</table>

Table A8.2 Notes:
- A Not applicable.

TABLE A8.3 Tolerances by Grade for Lots of Balls (Tolerances in millionths of an inch)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Allowable Lot Diameter Variation</th>
<th>Basic Diameter Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>400</td>
<td>±1000</td>
</tr>
<tr>
<td>500</td>
<td>1000</td>
<td>±2000</td>
</tr>
<tr>
<td>1000</td>
<td>2000</td>
<td>±5000</td>
</tr>
</tbody>
</table>
A9. MS19064 BALLS, BEARING, NICKEL-COPPER ALLOY (K-MONEL)

A9.1 Requirements

A9.1.1 Material—Nickel-copper alloy (K-Monel) conforming to the chemical composition of UNS N05500 in accordance with QQ-N-286 and as specified in procurement document.

A9.1.2 Hardness—Shall have a minimum hardness of 27 HRC or equivalent.

A9.1.3 Surface Roughness—Tolerance limits for surface roughness as specified in Table A9.2, and in accordance with ANSI B46.1.

A9.1.4 Material Density—Shall be 0.306 lb/in.³

A9.1.5 Part Number—The part number shall consist of the basic MS number followed by a dash number from Table A9.1 (see Fig. A9.2 for example).

A9.2 Notes

A9.2.1 All dimensions are in inches. Column headings in tolerance tables are in accordance with ABMA-STD-10.

A9.2.2 Dash numbers 20001 through 20024 were formerly dash 1 through 24.

A9.2.3 In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

A9.2.4 Referenced government (or nongovernment) documents of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DODISS) specified in the solicitation form a part of this specification to the extent specified herein.

Example: MS19064 - 10001

Dash Number

Basic MS Number

Note—MS19064-10001 indicates a Grade 100 nickel-copper alloy (K-Monel) with a basic diameter of 0.062500 in.

FIG. A9.1

FIG. A9.2 Example
A10. MEASUREMENT OF DEVIATION FROM SPHERICAL FORM

A10.1 General Information

A10.1.1 Deviation from spherical form on finished metal balls may occur in the form of two or more almost equally spaced waves around equatorial profiles. For balls having two waves or higher orders of even numbers of waves, the measurement of single diameters of the balls may be an adequate measure provided several equatorial profiles are subjected to measurement. However, as is most usual, odd numbers of waves of considerable magnitude may also be present which cannot be fully detected by simple two-point measurements.

A10.1.2 Because of the wide range of nominal diameters, from 0.3 mm to 4½ in., measurement of these errors of form can be a slow and difficult process, particularly on the smaller sizes of balls. Two basic methods for detecting errors of spherical form are in use. Most recently developed involves the use of specially designed, highly precise equipment generally identified by the term “Roundness Measuring Equipment.” Older equipment, still in common use today for the larger sizes of balls, involves the use of “Vee Blocks” and associated linear comparators of appropriate magnification.

### TABLE A9.1 Dash Numbers and Dimensions

<table>
<thead>
<tr>
<th>Nominal Ball Diameter</th>
<th>Basic Diameter</th>
<th>Grade</th>
<th>Dash Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>ØD</td>
<td></td>
<td>100</td>
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</tr>
<tr>
<td>1/16</td>
<td>0.062500</td>
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<td>20001</td>
</tr>
<tr>
<td>5/32</td>
<td>0.093750</td>
<td>10002</td>
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<tr>
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<td>0.156250</td>
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<td>20004</td>
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<tr>
<td>3/8</td>
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<td>7/32</td>
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<td>1.000000</td>
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<td>20021</td>
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<tr>
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<td>20022</td>
</tr>
<tr>
<td>3/8</td>
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</tr>
<tr>
<td>1/2</td>
<td>1.187500</td>
<td>10024</td>
<td>20024</td>
</tr>
</tbody>
</table>

A See Table A9.3 for tolerances.
B See A9.2.2.
A10.1.3 Since metal balls are essentially quite uniform as to errors of form in any one lot, it is considered sufficient to explore not more than three profiles in three equatorial planes each oriented approximately 90° from the other on individual balls of the sample.

A10.2 Method Using Roundness Measuring Equipment

A10.2.1 Two basic designs of Roundness Measuring Equipment are in use today. One design operates on the basis of stylus and associated linear transducer rotating around the ball in contact with its surface, and the other involves the rotation of the ball against a similar linear transducer. The extremely small motions of the stylus are, in both designs, suitably amplified and recorded on a polar chart which discloses the shape in the form of the number and extent of the waves but with radial deviations greatly magnified. The overall accuracy of the rotating spindle and associated amplifying and recording equipment must be very high, in the order of 0.025 µm or 1 µin. Extreme care must be taken in the interpretation of the polar charts. ANSI B89.3.1 defines several methods of chart interpretation. For finished metal balls, the minimum circumscribed circle (MCC) method is considered adequate.

A10.3 Method Using Vee Blocks

A10.3.1 For the larger sizes of balls, it is practical to use Vee Blocks having specific included angles and associated linear comparators or dial indicators of magnification appropriate for the grade of ball being measured. Fig. A10.1 illustrates the proper use of this type of equipment. This equipment is useful for detecting odd numbers of waves but no one Vee angle is adequate for the determination of all such odd orders of waves. The most desirable angles for wave numbers up to 21 appear to be 90° and 120°.

NOTE—The point of stylus/ball contact must be on Axis A-A which is the bisector of the Vee and Axis B-B which is the axis of the ball; also the spindle of the indicator must be in alignment with Axes A-A and B-B.

FIG. A10.1 Vee Block

A10.3.2 The magnification factors for the ratio of the indicator reading to the wave height or deviation from spherical form are shown in Table 8. In certain cases, combinations of Vee angles and numbers of waves present will show little or no indication—these are indicated by asterisks (*) and such readings should be disregarded. If the number of waves is known, the deviation from spherical form is obtained by dividing the indicator reading by the appropriate factor taken from this table.

A10.3.3 If, as is usual, the number of waves is unknown, readings should be taken on the three equatorial planes at 90° to each other, first on a simple two-point gage and then successively using the 90° and the 120° Vee Blocks. The deviation from spherical form is the highest of these three types of readings divided by two.

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Standard Specification for
Bearing, Roller, Needle: Thick Outer Ring With Rollers and Cage

This standard is issued under the fixed designation F 2246; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope
1.1 This specification covers needle roller bearings having thick outer rings, with rollers and cages.
1.2 The bearings being specified are intended to be used with hardened shafts (HRC58-65; see Test Methods E 18). For use with unhardened shafts, bearings should be used in conjunction with inner bearing ring as specified in MS51962 shown as bearing assemblies in MS500072.
1.3 The use of recycled materials that meet the requirements of the applicable material specification without jeopardizing the intended use of the item is encouraged.
1.4 Bearings designed to this specification are intended for use in applications requiring high radial load with minimal angular shaft misalignment.
1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information only.

NOTE 1—This specification contains many of the requirements of MS 51961, which was originally developed and maintained by the Defense Supply Center Richmond.

2. Referenced Documents
2.1 ASTM Standards:
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
2.2 ANSI Standard:
ANSI B46.1 Surface Texture (Surface Roughness, Waviness, and Lay)
2.3 SAE Standards:
SAE J-404 Chemical Compositions of SAE Alloy Steels
SAE AMS-STD-66 Steel: Chemical Composition and Hardness

2.4 Military Standards:
MIL-STD-130 Identification Marking of U.S. Military Property
MS500072 Bearing, Roller, Needle: Assembly (Thick Outer Race)
MS51962 Ring Bearing, Inner: For Needle Roller Bearing with Thick Outer Ring

2.5 American Bearing Manufacturers Association Standard:
ABMA 18.1 Needle Roller Bearings Radial, Inch Design

2.6 International Organization for Standardization Standards:
ISO 492 Rolling Bearings—Radial Bearings—Tolerances
ISO 3096 Rolling Bearings—Needle Rollers—Dimensions and Tolerances
ISO 5593 Rolling Bearings—Vocabulary

3. Terminology
3.1 Definitions—For definitions of terms used in this specification, refer to ISO 5593, Rolling Bearings—Vocabulary.
3.2 Definitions of Terms Specific to This Standard:
3.2.1 average life (L₅₀)—for a radial roller bearing, the number of revolutions that 50 % of a group of bearings will complete or exceed before the first evidence of fatigue develops.
3.2.1.1 Discussion—The average life is approximately five times the rating life.
3.2.2 basic dynamic load rating (Cᵣ)—for a radial roller bearing, that calculated, constant radial load that a group of apparently identical bearings with stationary outer rings can theoretically endure for a rating life of one million revolutions of the inner ring.
3.2.2.1 Discussion—Since applied loading as great as the basic dynamic load rating tends to cause local plastic deformation of the rolling surfaces, it is not anticipated that such heavy loading would normally be applied.
3.2.3 basic static load rating (C) — for a radial roller bearing, that uniformly distributed static radial load which produces a maximum contact stress at the center of the most heavily loaded rolling element contact of 580 000 psi (4000 Mpa).

3.2.3.1 Discussion — For this contact stress, a total permanent deformation of roller element plus raceway occurs, which is approximately 0.0001 of the roller diameter.

3.2.4 rating life (L10) — for a radial roller bearing, the number of revolutions that 90% of a group of bearings will complete or exceed before the first evidence of fatigue develops.

4. Ordering Information

4.1 When ordering parts in accordance with this specification, specify the following:
4.1.1 ASTM designation number, including year of issue,
4.1.2 Dash number (see Table 1),
4.1.3 Dimensions of roller bearings, including:
4.1.3.1 Bore diameter, in. (mm),
4.1.3.2 Outside diameter, in. (mm),
4.1.3.3 Width, in. (mm), and
4.1.3.4 Radius, in. (mm),
4.1.4 Load rating, including basic static load rating, lb (N) and basic dynamic load rating, lb (N), and
4.1.5 Approximate limiting speed, rpm.

5. Materials and Manufacture

5.1 Rollers — Rollers shall be manufactured of steel, alloy, grade E50100, E51100 or E52100 in accordance with SAE AMS-STD-66 or SAE J-404.

5.2 Rings — Rings shall be manufactured of steel, alloy or carbon, carburizing grade 4620, 4720, 8620, 8720, or 1010-1020 in accordance with SAE AMS-STD-66 or SAE 51100 or SAE 52100 in accordance with SAE J-404.

5.3 Cages — Cages shall be manufactured of steel, brass, or bronze, or other material in accordance with manufacturer’s standards.

6. Other Requirements

6.1 Heat Treatment:
6.1.1 Rollers — Rollers shall be through hardened to Rockwell HRC8-66 in accordance with Test Methods E 18.

6.1.2 Rings:
6.1.2.1 Steel 4620, 4720, 8620, 8720, and 1010-1020 shall be case hardened to Rockwell HRC8-65, in accordance with Test Methods E 18. Case depth shall be 0.025 in. (0.64 mm) minimum.

6.1.2.2 Steel SAE 51100 and SAE 52100 shall be through hardened to Rockwell HRC8-65, in accordance with Test Methods E 18.

6.2 Protective Coating:
6.2.1 Bearings shall be furnished without plating.

6.2.2 Manufacturer shall coat bearings with rust preventive film.

6.3 Lubrication — Bearings shall be furnished without lubrication.

7. Dimensions, Mass, and Permissible Variations

7.1 Products manufactured in accordance with this specification shall meet the requirements shown in Table 1.

7.2 Bearings are intended to be installed on shafts where maximum taper does not exceed 0.0005 in. per inch (0.0005 mm per mm) of bearing width.

7.3 Bearing bore should be checked using a “go” plug gage that is 0.0001 in. (0.0025 mm) less than the minimum diameter under the needle rollers column of Table 1, and “no go” plug gage that is 0.0001 in. (0.0025 mm) larger than the maximum diameter under the needle rollers column of Table 1. The “no go” gage may enter 25% of the roller length.

7.4 One end of the bearing must clear the maximum housing fillet radius shown in the radius column of Table 1. A minimum chamfer of 1/32 in. (0.79 mm) on the opposite end may be used in lieu of radius clearance. When ends are not identical, the marking (see Section 13) shall be applied to the end with the largest surface.

7.5 The needle roller diameter variation in each bearing shall fall within the limitations prescribed within ISO 3096 for Grade 5.

7.6 The run-out for each bearing outside diameter and raceway inside diameter shall be within the limitations prescribed in ISO 492 for the Normal Class.

7.7 Oil grooves and between one and four oil holes shall be included in accordance with manufacturer’s standard practice.

8. Workmanship, Finish and Appearance

8.1 Surface Finish:
8.1.1 Needle Rollers — Needle rollers shall have a maximum surface roughness, in accordance with ANSI B46.1, of 8 μin.Ra (0.20 μm Rα).

8.1.2 Rings — The raceway surface (bore) of the outer ring shall have a maximum surface roughness, in accordance with ANSI B46.1, of 20 μin. Rα (0.51 μm Rα).

9. Rating Life of Roller Bearing

9.1 Use the following equation to calculate rating life of roller bearing, L10, in millions of revolutions, at loads other than the basic dynamic load ratings:
F 2246 – 03
TABLE 1 Roller Bearing Dimensions
Fw
Bore Diameter, in.
Nom.

Min.

Max.

Nom.

Min.

Max.

C
Width, in.,
+0.000, -0.005

58

⁄
3⁄4
3⁄4
15⁄16
7⁄8

0.6258
0.7509
0.7509
0.8131
0.8759

0.6267
0.7518
0.7518
0.8143
0.8768

11⁄8
11⁄4
11⁄4
15⁄16
13⁄8

1.1245
1.2495
1.2495
1.3120
1.3745

1.1250
1.2500
1.2500
1.3125
1.3750

0.750
0.750
1.000
0.750
0.750

0.025
0.040
0.040
0.040
0.040

2520
2540
4120
2680
3210

2980
3180
4350
3210
3540

30200
24600
24600
22600
20700

⁄

0.8768
0.9393
1.0018
1.0018
1.0643

13⁄8
17⁄16
11⁄2
11⁄2
19⁄16

1.3745
1.4370
1.4995
1.4995
1.5620

1.3750
1.4375
1.5000
1.5000
1.5625

1.000
0.750
0.750
1.000
1.000

0.040
0.040
0.040
0.040
0.040

4810
3280
3670
5500
5280

4860
3590
3830
5250
5130

20700
20000
19200
19200
17800

Dash
Number
-1
-2
-3
-4
-5

D
Outside Diameter, in.

Radius,
in. (see 7.4)

Basic Static
Load Rating, lb

Basic Dynamic
Load Rating, lb

Approx. Limiting
Speed, rpm

-6
-7
-8
-9
-10

11⁄16

0.8759
0.9384
1.0009
1.0009
1.0634

-11
-12
-13
-14
-15

11⁄8
11⁄8
13⁄16
11⁄4
11⁄4

1.1259
1.1259
1.1885
1.2510
1.2510

1.1268
1.1268
1.1894
1.2519
1.2519

15⁄8
15⁄8
111⁄16
13⁄4
13⁄4

1.6245
1.6245
1.6870
1.7495
1.7495

1.6250
1.6250
1.6875
1.7500
1.7500

1.000
1.250
1.000
1.000
1.250

0.040
0.040
0.040
0.040
0.040

6190
8270
6150
6530
8730

5680
7120
5420
5870
7360

15700
15700
14600
14000
14000

-16
-17
-18
-19
-20

15⁄16
15⁄16
13⁄8
13⁄8
17⁄16

1.3135
1.3135
1.3760
1.3760
1.4385

1.3144
1.3144
1.3769
1.3769
1.4394

113⁄16
113⁄16
17⁄8
17⁄8
115⁄16

1.8120
1.8120
1.8745
1.8745
1.9370

1.8125
1.8125
1.8750
1.8750
1.9375

1.000
1.250
1.000
1.250
1.000

0.040
0.040
0.040
0.040
0.060

7050
9300
7220
9650
7480

6000
7530
6260
7840
6200

13300
13300
12600
12600
12100

-21
-22
-23
-24
-25

11⁄2
11⁄2
19⁄16
15⁄8
15⁄8

1.5010
1.5010
1.5635
1.6260
1.6260

1.5019
1.5019
1.5644
1.6269
1.6269

21⁄16
21⁄16
21⁄8
23⁄16
23⁄16

2.0619
2.0619
2.1244
2.1869
2.1869

2.6025
2.0625
2.1250
2.1875
2.1875

1.000
1.250
1.250
1.000
1.250

0.060
0.060
0.060
0.060
0.060

8130
10900
11000
8530
11500

7360
9270
8250
7360
9520

11700
11700
11200
10700
10700

-26
-27
-28
-29
-30

111⁄16
13⁄4
13⁄4
17⁄8
2

1.6885
1.7510
1.7510
1.8760
2.0011

1.6895
1.7520
1.7520
1.8770
2.0021

21⁄4
25⁄16
25⁄16
27⁄16
29⁄16

1.2494
2.3119
2.3119
2.4369
2.5619

2.2500
2.3125
2.3125
2.4375
2.5625

1.250
1.000
1.250
1.250
1.250

0.060
0.060
0.060
0.060
0.060

11600
8940
12000
13102
13700

9040
7760
9780
10400
10600

10000
9850
9850
9150
8350

-31
-32
-33
-34
-35

21⁄4
21⁄4
21⁄2
21⁄2
23⁄4

2.2511
2.2511
2.5011
2.5011
2.7511

2.2521
2.2521
2.5021
2.5021
2.7521

3
3
31⁄4
31⁄4
31⁄2

2.9994
2.9994
3.2494
3.2494
3.4992

3.0000
3.0000
3.2500
3.2500
3.5000

1.500
1.750
1.500
1.750
1.500

0.060
0.060
0.080
0.080
0.080

19100
23200
21600
26200
23300

14700
17100
13800
16400
16500

7600
7600
6800
6800
6150

-36
-37
-38
-39
-40

23⁄4
3
3
31⁄4
31⁄4

2.7511
3.0011
3.0011
3.2512
3.2512

2.7521
3.0023
3.0023
3.2524
3.2524

31⁄2
33⁄4
33⁄4
41⁄4
41⁄4

3.4992
3.7492
3.7492
4.2492
4.2492

3.5000
3.7500
3.7500
4.2500
4.2500

1.730
1.500
1.750
1.750
2.000

0.080
0.080
0.080
0.080
0.080

28200
25800
31200
35700
42100

19200
17600
20400
26600
30200

6150
5600
5600
5250
5250

-41
-42
-43
-44
-45

31⁄2
31⁄2
33⁄4
4
4

3.5012
3.5012
3.7512
4.0012
4.0012

3.5024
3.5024
3.7524
4.0024
4.0024

41⁄2
41⁄2
43⁄4
5
5

4.4992
4.4992
4.7492
4.9990
4.9990

4.5000
4.5000
4.7500
5.0000
5.0000

1.750
2.000
2.000
1.750
2.000

0.080
0.080
0.100
0.100
0.100

32200
43800
47000
36200
30400

21300
30700
32400
22500
33800

4350
4850
4500
4200
4200

-46
-47
-48
-49
-50

41⁄4
41⁄2
41⁄2
41⁄2
5

4.2512
4.5012
4.5012
4.5012
5.0013

4.2526
4.5026
4.5026
4.5026
5.0027

51⁄4
6
6
6
61⁄2

5.2490
5.9990
5.9990
5.9990
6.4990

5.2500
6.0000
6.0000
6.0000
6.5000

2.000
2.000
2.250
2.500
2.000

0.100
0.100
0.100
0.100
0.100

52200
43600
62800
72700
60800

34200
30900
47900
53300
46100

3950
3850
3850
3850
3400

-51
-52
-53
-54
-55

5
51⁄2
51⁄2
53⁄4
6

5.0013
5.5013
5.5013
5.7313
6.0013

5.0027
5.5027
5.5027
5.7327
6.0027

61⁄2
7
7
71⁄4
1
7 ⁄2

6.4990
6.9990
6.9990
7.2490
7.4988

6.5000
7.0000
7.0000
7.2500
7.5000

2.500
2.500
3.000
3.000
2.500

0.100
0.100
0.100
0.120
0.120

70900
84200
105000
109000
93200

52000
58000
69100
70600
61900

3400
3100
3100
2950
2800

-56
-57
-58
-59

6
61⁄2
61⁄2
71⁄4

6.0013
6.5013
6.5013
7.2514

6.0027
6.5029
6.5029
7.2530

71⁄2
8
8
91⁄8

7.4988
7.9988
7.9988
9.1238

7.5000
8.0000
8.0000
9.1250

3.000
2.500
3.000
3.000

0.120
0.120
0.120
0.120

116000
99000
124000
134000

73800
63900
76300
88600

2800
2600
2600
2300

78

⁄

15 16

1
1

3


where:
\[ L_{10} = [C_r/P]^{1/3} \quad (1) \]

9.1.1 The rating life of roller bearings as calculated in Eq 1 are assumed to be operating under the following conditions:
9.1.1.1 The inner ring is rotating,
9.1.1.2 The outer ring is stationary,
9.1.1.3 The load is steady,
9.1.1.4 The revolutions per minute are uniform,
9.1.1.5 The roller bearing is thoroughly lubricated,
9.1.1.6 The maximum bearing temperature does not exceed 300°F (149°C), and
9.1.1.7 Any shaft misalignment does not exceed 0.0005 in. per inch (0.0005 mm per mm) of bearing width.
9.1.2 Eq 1 is not valid for an applied load greater than one-half the basic dynamic load rating.

10. Inspection
10.1 Inspection of the product shall be agreed upon between the purchaser and the supplier as part of the purchase contract.

11. Rejection and Rehearing
11.1 Products that fail to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for rehearing.

12. Certification
12.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

13. Product Marking
13.1 Marking shall consist of the part number and the manufacturer’s identification in accordance with MIL-STD-130.
13.1.1 The part number shall consist of the MS51961 plus the dash number (see Table 1). Example: MS51961-1.

14. Keywords
14.1 cage; MS51961; needle roller; oil groove; oil hole; outer ring; radial; RBEC 1; roller bearing
Standard Specification for
Stainless Steel and Nickel Alloy Bolts, Hex Cap Screws, and
Studs, for Heat Resistance and High Temperature
Applications

This standard is issued under the fixed designation F 2281; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the chemical and mechanical
requirements for stainless steel and nickel alloy bolts, hex cap
screws, and studs, ¼ in. diameter and larger, intended for use
at temperatures up to 1800°F (982°C), and in applications
where resistance to heat and the effects of high temperature are
to be considered. See Appendix X1 for Service Application. A
wide variety of materials are covered in this specification
which can be used at high temperatures as a function of the
specific alloy properties, as well as environmental require-
ments including corrosive environments.

1.2 The values stated in inch-pound units are to be regarded
as the standard.

1.3 This standard does not purport to address all of the
safety concerns, if any, associated with its use. It is the
responsibility of the user of this standard to establish appro-
priate safety and health practices and determine the applica-
bility of regulatory requirements prior to use.

2. Referenced Documents

2.1 ASTM Standards:
A 262 Practices for Detecting Susceptibility to Intergranu-
lar Attack in Austenitic Stainless Steels
A 276 Specification for Stainless Steel Bars and Shapes
A 342/A 342M Test Methods for Permeability of Feebly
Magnetic Materials
A 380 Practice for Cleaning, Descaling, and Passivation of
Stainless Steel Parts, Equipment, and Systems
A 484/A 484M Specification for General Requirements for
Stainless Steel Bars, Billets, and Forgings
A 493 Specification for Stainless Steel Wire and Wire Rods
for Cold Heading and Cold Forging
A 564/A 564M Specification for Hot-Rolled and Cold-
Finished Age-Hardening Stainless Steel Bars and Shapes
A 582/A 582M Specification for Free-Machining Stainless
Steel Bars
A 751 Test Methods, Practices, and Terminology for
Chemical Analysis of Steel Products
B 637 Specification for Precipitation-Hardening Nickel Al-
loy Bars, Forgings, and Forging Stock for High-
Temperature Service
B 880 Specification for General Requirements for Chemical
Check Analysis Limits for Nickel, Nickel Alloys, and
Cobalt Alloys
D 3951 Practice for Commercial Packaging
E 21 Test Methods for Elevated Temperature Tension Tests
of Metallic Materials
E 29 Practice for Using Significant Digits in Test Data to
Determine Conformance with Specifications
E 76 Test Methods for Chemical Analysis of Nickel-Copper
Alloys
E 139 Test Methods for Conducting Creep, Creep-Rupture,
and Stress-Rupture Tests of Metallic Materials
E 292 Test Methods for Conducting Time-for-Rupture
Notch Tension Tests of Materials
E 353 Test Methods for Chemical Analysis of Stainless,
Heat-Resisting, Maraging, and Other Similar Chromium-
Nickel-Iron Alloys
E 354 Test Methods for Chemical Analysis of High-
Temperature, Electrical, Magnetic, and Other Similar Iron,
Nickel, and Cobalt Alloys
F 606 Test Methods for Determining the Mechanical Props-
erties of Externally and Internally Threaded Fasteners,
Washers, and Rivets
F 788/F 788M Specification for Surface Discontinuities of
Bolts, Screws, and Studs, Inch and Metric Series
F 1470 Guide for Fastener Sampling for Specified Mechani-
cal Properties and Performance Inspection

1 This specification is under the jurisdiction of ASTM Committee F16 on
Fasteners and is the direct responsibility of Subcommittee F16.04 on Nonferrous
Fasteners.
2 Annual Book of ASTM Standards, Vol 01.03.
3 Annual Book of ASTM Standards, Vol 03.04.
6 Annual Book of ASTM Standards, Vol 03.01.
8 Annual Book of ASTM Standards, Vol 03.05.
9 Annual Book of ASTM Standards, Vol 01.08.

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2.2 ASME Standards:
B1.1 Unified Inch Screw Threads
B18.2.1 Square and Hex Bolts and Screws, (Inch Series)

3. Terminology

3.1 Definitions:
3.1.1 heat resistance—the extent to which a material retains useful properties as measured during exposure of the material to a specified temperature and environment for a specified time.

3.2 Definitions of Terms Specific to This Standard:
3.2.1 high temperature—defined solely for the purpose of this document as a range in temperature from 500°F (260°C) to 1800°F (982°C). Materials listed as high temperature alloys are designed to maintain their anticipated strength and characteristics within this range.

4. Classification

4.1 Three types of material, see Appendix X1 for Service Application, are covered in this specification and are classified into the following:
4.1.1 Type I—Heat Resisting Alloys for Continuous Service Applications:
4.1.1.1 Class A—Austenitic Grades:

<table>
<thead>
<tr>
<th>Alloy Grade</th>
<th>UNS Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>304</td>
<td>S30400</td>
</tr>
<tr>
<td>304L</td>
<td>S30403</td>
</tr>
<tr>
<td>316</td>
<td>S31600</td>
</tr>
<tr>
<td>316L</td>
<td>S31603</td>
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4.1.1.2 Class B—Martensitic Grades:

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<th>UNS Designation</th>
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</thead>
<tbody>
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<td>S41000</td>
</tr>
<tr>
<td>416</td>
<td>S41600</td>
</tr>
<tr>
<td>431</td>
<td>S43100</td>
</tr>
</tbody>
</table>

4.1.1.3 Class C—Ferritic Grades:

<table>
<thead>
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<th>UNS Designation</th>
</tr>
</thead>
<tbody>
<tr>
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<td>S43000</td>
</tr>
<tr>
<td>430F</td>
<td>S43020</td>
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4.1.2 Type II—Heat Resisting Alloys for Continuous and Intermittent Service Applications:

<table>
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<th>Alloy Grade</th>
<th>UNS Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>309</td>
<td>S30900</td>
</tr>
<tr>
<td>310</td>
<td>S31000</td>
</tr>
<tr>
<td>321</td>
<td>S32100</td>
</tr>
<tr>
<td>330</td>
<td>N08330</td>
</tr>
<tr>
<td>347</td>
<td>S34700</td>
</tr>
</tbody>
</table>

4.1.3 Type III—High Temperature Alloys for Continuous and Intermittent Service Applications:
4.1.3.1 Class A—Nickel based alloy:

<table>
<thead>
<tr>
<th>Alloy Grade</th>
<th>UNS Designation</th>
</tr>
</thead>
<tbody>
<tr>
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<td>N06600</td>
</tr>
<tr>
<td>601</td>
<td>N06601</td>
</tr>
</tbody>
</table>

4.1.3.2 Class B—Precipitation Hardened alloy:

<table>
<thead>
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<th>Alloy Grade</th>
<th>UNS Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>660</td>
<td>S66286</td>
</tr>
</tbody>
</table>

4.1.3.3 Class C—Precipitation Hardened alloy:

<table>
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<th>UNS Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>718</td>
<td>N07718</td>
</tr>
</tbody>
</table>

5. Ordering Information

5.1 Orders for bolts, hex cap screws, and studs under this specification shall include the following information:
5.1.1 ASTM designation and year date. When year date is not specified, the latest issue shall be invoked;
5.1.2 Quantity (number of pieces of each item),
5.1.3 Item name (that is, bolt, hex cap screw, or stud),
5.1.4 Size (nominal diameter, threads per inch, length),
5.1.5 Type, class, and alloy grade (see 4.1), and
5.1.6 Condition (see 6.2.3).

5.2 Orders for bolts, hex cap screws, and studs under this specification may include the following optional requirements:
5.2.1 Forming (see 6.2.1),
5.2.2 Thread type (see 6.2.2),
5.2.3 Corrosion tests (see 13.1.2.1),
5.2.4 Finish (see 11.3),
5.2.5 Test reports (see 19.2), and
5.2.6 Supplementary Requirements, if any, to be specified on the order (see S1 through S8).

6. Materials and Manufacture

6.1 Material:

6.1.1 Specifications A 276, A 484, A 493, A 564/A 564M, A 582/A 582M, B 637 are noted for information only as suitable sources of material for the manufacture of bolts, hex cap screws, and studs to this specification.

6.1.2 The bolts, hex cap screws, and studs shall be manufactured from material having a chemical composition conforming to the requirements listed in Table 1 and capable of developing the mechanical property requirements listed in Table 2 for the finished fastener.

6.1.3 Various grades of material having unique heat resisting or high temperature characteristics are specified in this specification. A guide to their application is listed in Appendix X1 to assist in the selection of the fastener material.

6.1.4 The form and condition of the raw material shall be at the option of the manufacturer but shall be such that the finished fastener conforms to all the specified requirements.

6.2 Manufacture:

6.2.1 Forming—Unless otherwise specified, the fasteners shall be cold formed, hot formed, or machined from suitable material, at the option of manufacturer.

6.2.2 Threads—Unless otherwise specified, the threads shall be rolled or cut, at the option of the manufacturer.

6.2.3 Condition—The fasteners shall be furnished in one of the following conditions and shall be agreed upon between the manufacturer and the purchaser at the time of the inquiry and order.
**TABLE 1 Chemical Requirements**

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Carbon</th>
<th>Mang.</th>
<th>Phos.</th>
<th>Sulfur</th>
<th>Silicon</th>
<th>Chromium</th>
<th>Nickel</th>
<th>Copper</th>
<th>Moly</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I, Class A, Heat Resisting Austenitic Grades</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>304</td>
<td>0.08</td>
<td>2.00</td>
<td>0.045</td>
<td>0.030</td>
<td>1.00</td>
<td>18.0/20.0</td>
<td>8.0/10.5</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>304L</td>
<td>0.03</td>
<td>2.00</td>
<td>0.045</td>
<td>0.030</td>
<td>1.00</td>
<td>18.0/20.0</td>
<td>8.0/12.0</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>316</td>
<td>0.08</td>
<td>2.00</td>
<td>0.045</td>
<td>0.030</td>
<td>1.00</td>
<td>16.0/18.0</td>
<td>10.0/14.0</td>
<td>2.00/3.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>316L</td>
<td>0.03</td>
<td>2.00</td>
<td>0.045</td>
<td>0.030</td>
<td>1.00</td>
<td>16.0/18.0</td>
<td>10.0/14.0</td>
<td>2.00/3.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type I, Class B, Heat Resisting Martensitic Grades</td>
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<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
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<td>0.040</td>
<td>0.030</td>
<td>1.00</td>
<td>11.5/13.5</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>416</td>
<td>0.15</td>
<td>1.25</td>
<td>0.060</td>
<td>0.15 min</td>
<td>1.00</td>
<td>12.0/14.0</td>
<td></td>
<td></td>
<td>0.60</td>
<td></td>
</tr>
<tr>
<td>431</td>
<td>0.20</td>
<td>1.00</td>
<td>0.040</td>
<td>0.030</td>
<td>1.00</td>
<td>15.0/17.0</td>
<td>1.25/2.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type I, Class C, Heat Resisting Ferritic Grades</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>0.040</td>
<td>0.030</td>
<td>1.00</td>
<td>16.0/18.0</td>
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<td></td>
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<td>0.060</td>
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<td>16.0/18.0</td>
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<td></td>
<td>0.60</td>
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<tr>
<td>Type II, Heat Resisting Austenitic Grades</td>
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<td>0.030</td>
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<td>22.0/24.0</td>
<td>12.0/15.0</td>
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<td>0.030</td>
<td>1.50</td>
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<td>19.0/22.0</td>
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<tr>
<td>321</td>
<td>0.08</td>
<td>2.00</td>
<td>0.045</td>
<td>0.030</td>
<td>1.00</td>
<td>17.0/19.0</td>
<td>9.0/12.0</td>
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<td>330</td>
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<td>0.030</td>
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<td>17.0/19.0</td>
<td>9.0/13.0</td>
<td>Cb+Ta10×Cmin</td>
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<td>0.015</td>
<td>0.50</td>
<td>14.0/17.0</td>
<td>72.0 min</td>
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<td>21.0/25.0</td>
<td>58.0/63.0</td>
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<td>Type III, Class B, High Temperature, Precipitation Hardened Grade</td>
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<tr>
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<td>0.040</td>
<td>0.030</td>
<td>1.00</td>
<td>13.5/16.0</td>
<td>24.0/27.0</td>
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<td>0.015</td>
<td>0.35</td>
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<td>2.80/3.30</td>
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### Type and Class Conditions

<table>
<thead>
<tr>
<th>Type</th>
<th>Class</th>
<th>Condition</th>
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</thead>
<tbody>
<tr>
<td>I</td>
<td>A</td>
<td>A, CWA, HWA</td>
</tr>
<tr>
<td>I</td>
<td>B</td>
<td>H, HT</td>
</tr>
<tr>
<td>I</td>
<td>C</td>
<td>A, CWA, HWA</td>
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<tr>
<td>II</td>
<td>A</td>
<td>A, CWA, HWA</td>
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<tr>
<td>III</td>
<td>B</td>
<td>AH1, AH2 or AH3</td>
</tr>
<tr>
<td>III</td>
<td>C</td>
<td>AH4</td>
</tr>
</tbody>
</table>

**Machined from annealed or solution-annealed stock.**

- **CWA:** Cold formed from annealed or solution-annealed stock and then re-annealed
- **HWA:** Hot formed from annealed or solution-annealed stock and then re-annealed

- **H**: Hardened and tempered at 1050°F (565°C) minimum
- **HT**: Hardened and tempered at 525°F (274°C) minimum
- **AH1**: Solution Treated at 1850°F (1010°C) and Precipitation Hardened (Aging)
- **AH2**: Solution Treated at 1700°F (927°C) and Precipitation Hardened (Aging)
- **AH3**: Solution Treated at 1850°F (1010°C) and Double Aged
- **AH4**: Solution Treated at 1725°F (941°C) to 1850°F (1010°C) and Precipitation Hardened (Aging)

6.2.4 **Heat Treatment:**

6.2.4.1 **Condition A**—(Austenitic Alloys Type I Class A and Type II), shall be heated to 1850 to 1950°F (1010 to 1066°C), held for a sufficient time, then cooled at a rate sufficient to prevent the precipitation of carbides and to provide the specified properties.

6.2.4.2 **Condition A**—(Ferritic Alloys Type I Class C), shall be heated to 1400 to 1500°F (760 to 816°C), held for a sufficient time, and then air cooled to provide the specified properties.

6.2.4.3 **Condition A**—(Nickel Alloy Type III Class A), shall be heated to 1600° to 1800°F (871 to 982°C), held for ten to fifteen minutes, and either water quenched or air cooled.

6.2.4.4 **Condition CWA**—(Austenitic Alloys Type I Class A and Type II), shall be cold formed from annealed or solution annealed stock and then re-annealed or re-solution annealed in accordance with 6.2.4.1 after all cold working (including heading and threading) has been completed.

6.2.4.5 **Condition CWA**—(Ferritic Alloys Type I Class C), shall be cold formed from annealed or solution annealed stock and then re-annealed or re-solution annealed in accordance with 6.2.4.2 after all cold working (including heading and threading) has been completed.

6.2.4.6 **Condition CWA**—(Nickel Alloy Type III Class A), shall be cold formed from annealed stock and then re-annealed...
TABLE 2 Mechanical Property Requirements at Room Temperature

<table>
<thead>
<tr>
<th>Alloy Grades</th>
<th>Condition</th>
<th>Marking</th>
<th>Nominal Diameter, in.</th>
<th>Full-Size Tests</th>
<th>Rockwell Hardness</th>
<th>Machined Specimen Tests</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tensile Strength, min, ksi</td>
<td>Yield Strength, min, ksi</td>
<td>Tensile Strength, min, ksi</td>
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<tr>
<td>Type I, Class A, Heat Resisting Austenitic Grades</td>
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<tr>
<td>304, 304L A</td>
<td>F1A</td>
<td>All Diameters</td>
<td>75</td>
<td>30</td>
<td>65 to 95 HRB</td>
<td>75</td>
</tr>
<tr>
<td>CWA F1B</td>
<td>All Diameters</td>
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<td>30</td>
<td>65 to 95 HRB</td>
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</tr>
<tr>
<td>HWA F1C</td>
<td>All Diameters</td>
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<td>65 to 95 HRB</td>
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<td>316, 316L A</td>
<td>F1D</td>
<td>All Diameters</td>
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<td>65 to 95 HRB</td>
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</tr>
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<td>CWA F1E</td>
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<td>65 to 95 HRB</td>
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<td>HWA F1F</td>
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<td>65 to 95 HRB</td>
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<td>Type I, Class B, Heat Resisting Martensitic Grades</td>
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</tr>
<tr>
<td>410, 416 H</td>
<td>F1G</td>
<td>Up to 4 Diameters</td>
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<td>85</td>
<td>20 to 30 HRC</td>
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<td>H1 F1H</td>
<td>Up to 4 Diameters</td>
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<td>120</td>
<td>34 to 45 HRC</td>
<td>160</td>
<td>120</td>
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<tr>
<td>431 H</td>
<td>F1I</td>
<td>All Diameters</td>
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<td>25 to 32 HRC</td>
<td>125</td>
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<tr>
<td>H1 F1J</td>
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<td>40 to 48 HRC</td>
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<td>140</td>
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<td>430, 430F A</td>
<td>F1K</td>
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<td>65 to 95 HRB</td>
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<td>CWA F1L</td>
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<tr>
<td>309, 310 A</td>
<td>F2A</td>
<td>All Diameters</td>
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<td>65 to 95 HRB</td>
<td>75</td>
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<tr>
<td>CWA F2B</td>
<td>All Diameters</td>
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<td>30</td>
<td>65 to 95 HRB</td>
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<td>30</td>
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<td>HWA F2C</td>
<td>All Diameters</td>
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<td>65 to 95 HRB</td>
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<td>321, 347 A</td>
<td>F2D</td>
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<tr>
<td>CWA F2E</td>
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<td>330 A</td>
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<td>HWA F2I</td>
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<td>65 to 95 HRB</td>
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<td>Type III, Class A, High Temperature, Nickel Alloy Grades</td>
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<tr>
<td>600, 601 A</td>
<td>F3A</td>
<td>All Diameters</td>
<td>80</td>
<td>25</td>
<td>65 to 85 HRB</td>
<td>75</td>
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<td>CWA F3B</td>
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<td>65 to 85 HRB</td>
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<tr>
<td>HWA F3C</td>
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<td>65 to 85 HRB</td>
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<td>25</td>
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<td>Type III, Class B, High Temperature, Precipitation Hardened Grade</td>
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<td>660 AH1</td>
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<td>22 to 37 HRC</td>
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<td>85</td>
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<tr>
<td>Note: Condition AH1 results in increased rupture strength after aging, while Condition AH2 results in better ductility and higher hardness.</td>
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<tr>
<td>718 AH4</td>
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<td>185</td>
<td>150</td>
<td>36 to 48 HRC</td>
<td>180</td>
</tr>
</tbody>
</table>

Note: Condition HT—(Martensitic Alloys Type I Class B), shall be hardened by heating to 1800 to 1900°F (982 to 1038°C), held for at least ½ h and rapid air or oil quenched, then reheated to 525°F (274°C) minimum for at least 1 h and air cooled to provide the specified properties.

6.2.4.11 Condition HT—(Martensitic Alloys Type I Class B), shall be hardened by heating to 1800 to 1900°F (982 to 1038°C), held for at least ½ h and rapid air or oil quenched, then reheated to 525°F (274°C) minimum for at least 1 h and air cooled to provide the specified properties.

6.2.4.12 Condition AH1—(Precipitation Hardened Alloy Type III Class B), shall be solution treated at 1800 to 1900°F (982 to 1038°C), held for 1 h at heat, then cooled rapidly. Precipitation Hardening (Aging) shall be performed by heating to 1300 to 1400°F (704 to 760°C), holding for 12 to 16 h at heat then air cooled. See Note 1.

6.2.4.13 Condition AH2—(Precipitation Hardened Alloy Type III Class B), shall be solution treated at 1650 to 1750°F (899 to 954°C), held for 2 h at heat, then cooled rapidly. Precipitation Hardening (Aging) shall be performed by heating to 1300 to 1400°F (704 to 760°C), holding for 12 to 16 h at heat then air cooled. See Note 1.

Note 1—Condition AH1 results in increased rupture strength after aging, while Condition AH2 results in better ductility and higher hardness.

in accordance with 6.2.4.3 after all cold working (including heading and threading) has been completed.

6.2.4.7 Condition HWA—(Austenitic Alloys Type I Class A and Type II), shall be hot formed from annealed or solution-annealed stock and then re-annealed or re-solution annealed in accordance with 6.2.4.1 after all hot forming has been completed.

6.2.4.8 Condition HWA—(Ferritic Alloys Type I Class C), shall be hot formed from annealed or solution-annealed stock and then re-annealed or re-solution annealed in accordance with 6.2.4.2 after all hot forming has been completed.

6.2.4.9 Condition HWA—(Nickel Alloy Type III Class A), shall be hot formed from annealed or solution-annealed stock and then re-annealed or re-solution annealed in accordance with 6.2.4.3 after all hot forming has been completed.

6.2.4.10 Condition H—(Martensitic Alloys Type I Class B), shall be hardened by heating to 1800 to 1900°F (982 to 1038°C), held for at least ½ h and rapid air or oil quenched, then reheated to 1050°F (565°C) minimum for at least 1 h and air cooled to provide the specified properties.
6.2.4.14 Condition AH3—(Precipitation Hardened Alloy Type III Class B), shall be solution treated at 1800 to 1900°F (982 to 1038°C), held for 1 h at heat, then cooled rapidly. Precipitation Hardening (Aging) shall be performed by heating to 1425 ± 25°F (775 ± 14°C) holding for 16 h at heat then air cooled. Heated again to 1200 ± 25°F (650 ± 14°C) holding for 16 h at heat then air cooled.

6.2.4.15 Condition AH4—(Precipitation Hardened Alloy Type III Class C), shall be solution treated at 1725°F (941°C) to 1850°F (1010°C), held at the selected temperature for a time commensurate with cross-sectional thickness, and cooled at a rate equivalent to an air cool or faster. Solution treating commensurate with cross-sectional thickness, and cooled at a rate equivalent to an air cool or faster. Solution treating temperatures shall be controlled in a range of ±25°F (±14°C). Precipitation Hardening (Aging) shall be performed by heating to 1325°F (718°C) held at heat for 8 h, cooled to 1150°F (621°C) at a rate of 100°F (56°C) per hour, held for 8 h at heat and air cooled. Alternatively, parts may be furnace cooled to 1150°F (621°C) at any rate provided the time at 1150°F (621°C) is adjusted so the total heat treat time is 18 h minimum. Precipitation treatment temperatures and cooling rates shall be controlled in the range of ±15°F (±8°C).

7. Chemical Composition

7.1 Chemical Composition—Bolts, hex cap screws, and studs shall conform to the chemical composition requirements prescribed in Table 1 for the specified alloy grade.

7.2 Product Analysis:

7.2.1 When a product analysis is made by the purchaser from finished fasteners representing each lot, the chemical composition thus determined shall conform to the requirements listed in Table 1 for the specified alloy grade, subject to the Product Analysis tolerance listed in Specifications A 484 and B 880.

7.2.2 In the event of a discrepancy, a referee chemical analysis of samples, taken from each lot, shall be made in accordance with 14.1 and 15.1.

8. Mechanical Properties

8.1 Bolts, hex cap screws, and studs shall meet the applicable mechanical properties listed in Table 2 for the specified alloy grade and condition when tested at room temperature, in accordance with the mechanical properties requirements specified herein for the type, grade, diameter, and length.

8.2 Mechanical Test Requirements:

8.2.1 Bolts and hex cap screws which meet the minimum requirements for length, and have a maximum 160 000 pound tensile load, shall have a full size wedge tensile strength and yield strength test performed as outlined in Section 15. For bolts and hex cap screws which exceed the 160 000 pound limit, a Machined Specimen tensile strength, yield strength, and elongation test performed as outlined in Section 15 may be substituted for the full size wedge test. In addition, for bolts and hex cap screws that are less than the minimum length requiring tension tests, either a full size axial tensile strength test or a Rockwell hardness test results, the precedence sequence shall be the same as the sequence listed in this section for acceptance purposes. That is, if parts pass axial tensile but fail Rockwell hardness they are acceptable; however, if they fail axial tensile and pass Rockwell hardness they are not acceptable.

8.3 In the event of a discrepancy between full size wedge test, full size axial test, machined specimen test, and Rockwell hardness test results, the precedence sequence shall be the same as the sequence listed in this section for acceptance purposes. That is, if parts pass axial tensile but fail Rockwell hardness they are acceptable; however, if they fail axial tensile and pass Rockwell hardness they are not acceptable.

8.4 If tests to determine high temperature properties are required on Type III High Temperature Alloys, supplementary requirements S8 shall be specified in the inquiry and order and high temperature testing shall be performed and meet the applicable mechanical properties listed in Table 3.

9. Corrosion Resistance

9.1 Carbide Precipitation:

9.1.1 The type I, class A austenitic alloys listed in 4.1.1.1 and all type II austenitic alloys listed in 4.1.2 shall be capable

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Tensile Strength, ksi</th>
<th>Yield Strength, ksi</th>
<th>Elongation in 2 in., %</th>
</tr>
</thead>
<tbody>
<tr>
<td>°F</td>
<td>°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class A—Nickel Based Alloys</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alloy Grade 600 Annealed at 1600°F (871°C)</td>
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</tr>
<tr>
<td>600</td>
<td>316</td>
<td>89.0</td>
<td>34.0</td>
</tr>
<tr>
<td>1000</td>
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</tr>
<tr>
<td>1800</td>
<td>982</td>
<td>11.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

| Class B—Precipitation Hardened Alloys |
| Alloy Grade 660 |
| 800         | 427                   | 104.0               | 54.5                   |
| 1000        | 538                   | 94.8                | 51.5                   |
| 1200        | 649                   | 73.5                | 46.5                   |
| 1400        | 760                   | 37.3                | 36.6                   |
| 1800        | 982                   | 8.7                 | 7.5                    |

| Class C—Precipitation Hardened Alloys |
| Alloy Grade 718 |
| 600         | 316                   | 184.0               | 156.0                  |
| 1000        | 538                   | 173.0               | 148.0                  |
| 1200        | 649                   | 145.0               | 125.0                  |
| 1400        | 760                   | 124.0               | 116.0                  |

8.2.2 Studs which meet the minimum requirements for length and have a maximum 160 000 pound tensile load, shall have a full size axial tensile strength test and yield strength test performed as outlined in Section 15. For studs which exceed the 160 000 pound limit, a Machined Specimen tensile strength, yield strength, and elongation test performed as outlined in Section 15 may be substituted for the full size axial test. In addition, for studs that are less than the minimum length requiring tension tests, either a full size axial tensile strength test or a Rockwell hardness test shall be required as outlined in Section 15. In all cases, full size axial tensile strength testing shall be performed whenever possible.
of passing the test for susceptibility to intergranular corrosion in accordance with Practice E of Practices A 262.

9.1.2 As stated in Practices A 262, samples may be subjected to the faster and more severe screening test in accordance with Practice A. Failing Practice A, specimens may be tested in accordance with Practice E and be considered satisfactory if passing Practice E.

10. Dimensions

10.1 Bolts and Hex Cap Screws:

10.1.1 Unless otherwise specified, the dimensions shall be in accordance with the requirements of ASME B18.2.1 for Hex Cap Screws.

10.1.2 When specified, the dimensions of bolts shall be in accordance with the requirements of ASME B18.2.1 (type as specified), or such other dimensions as shall be specified.

10.2 Studs:

10.2.1 Dimensions of studs shall be specified by the purchaser.

10.2.2 Stud Type:

10.2.2.1 Continuous thread.

10.2.2.2 Double end clamping (also known as stud bolt or bolt stud).

10.2.2.3 Double end interference (also known as tap-end stud).

10.2.2.4 Other studs as shall be specified by the purchaser.

10.2.3 Threads—Unless otherwise specified, studs shall have Class 2A threads in accordance with ASME B1.1.

10.2.4 Points—Unless otherwise specified, the points shall be flat and chamfered or rounded at the option of the manufacturer.

11. Workmanship, Finish and Appearance

11.1 Surface Discontinuities—For fasteners with specified minimum tensile strengths of 90 000 psi and higher the requirements in Specification F 788/F 788M shall apply.

11.2 Cleaning and Descaling—The fasteners shall be descaled, or cleaned, or both, in accordance with Specification A 380.

11.3 Protective Finishes—Unless otherwise specified, the fasteners shall be furnished without an additive chemical or metallic finish.

12. Sampling

12.1 A lot, for the purposes of selecting test specimens and inspection, shall be as defined in Guide F 1470.

13. Number of Tests and Retests

13.1 Number of Tests:

13.1.1 Mechanical Tests—The mechanical property requirements listed in Table 2 shall be met for all lots produced and submitted for testing. The manufacturer shall make sample inspections in accordance with Guide F 1470 Detection Process, to ensure the product conforms to the specified requirements. When tests of individual shipments are required, Supplementary Requirement S1 shall be specified in the inquiry and order.

13.1.2 Corrosion Resistance Tests:

13.1.2.1 Unless otherwise specified, inspection for corrosion resistance shall be in accordance with the manufacturer’s standard quality control practices. No one specific method of inspection is required, but the fasteners shall be produced from suitable raw material and manufactured, by properly controlled practices, to maintain resistance to corrosion. When corrosion tests are required, Supplementary Requirement S6 shall be specified in the inquiry and order, except as noted in 13.1.2.2.

13.1.2.2 Products that have been hot worked shall be solution annealed. Sampling for determination of freedom from precipitated carbides shall be in accordance with Guide F 1470 Detection Process.

13.1.3 Sampling for determination of freedom from surface discontinuities shall be in accordance with Guide F 1470 Detection Process.

14. Specimen Preparation

14.1 Chemical Tests—When required, samples for chemical analysis shall be taken by drilling, sawing, milling, turning, clipping, or other such methods capable of producing representative samples.

14.2 Mechanical Tests:

14.2.1 When required, machined tension specimens shall be machined from the fastener in accordance with Test Methods F 606. The largest test specimen that can be machined from the bolt, hex cap screw, or stud shall be used.

14.2.2 When required, the hardness shall be determined on the finished fastener in accordance with Test Methods F 606.

14.3 Corrosion Resistance—When required, test specimens shall be prepared in accordance with Practices A 262.

15. Test Methods

15.1 Chemical Analysis:

15.1.1 The fastener manufacturer may accept the chemical analysis of each heat of raw material purchased and reported on the raw material certification furnished by the raw material producer. The fastener manufacturer is not required to do any further chemical analysis testing provided that precise heat lot traceability has been maintained throughout the manufacturing process on each lot of fasteners produced and delivered.

15.1.2 The chemical composition of stainless steel fasteners shall be determined in accordance with Test Methods A 751.

15.1.3 The chemical composition of nickel alloy fasteners shall be determined in accordance with Test Method E 76, E 353, E 354 or other equivalent method.

15.2 Mechanical Tests:

15.2.1 When full-size tests are to be performed, the yield strength, wedge tensile strength, or axial tensile strength, as required by Section 8 above, shall be determined on each sample in accordance with the appropriate methods of Test Methods F 606.

15.2.2 Full-size bolts and hex cap screws subject to tension tests shall be tested using a wedge under the head. The wedge shall be 10° for bolts over 0.750-in. nominal diameter and less and 6° for bolts over 0.750-in. diameter.

15.2.3 When machined specimen tests are necessary (see Section 8), the yield strength, tensile strength, and elongation shall be determined on each sample in accordance with Test Methods F 606.
15.2.4 Bolts, hex cap screws, and studs that are less than the minimum length requiring tension tests shall be tested in accordance with Test Method F 606.

15.2.5 The hardness shall be determined in accordance with Test Methods F 606. A minimum of two readings shall be made on each sample, each of which shall conform to the specified requirements.

15.3 Corrosion Resistance—When required or when specified on the purchase order or inquiry, corrosion tests to determine freedom from precipitated carbides shall be performed in accordance with Practices A 262, Practice A or E, as applicable.

16. Significance of Numerical Limits

16.1 For the purpose of determining compliance with the specified limits for properties listed in this specification, an observed value or calculated value shall be rounded, in accordance with Practice E 29.

17. Inspection

17.1 If source inspection is required by the purchaser, Supplementary Requirement S3 shall be specified in the inquiry, order, or contract.

17.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer’s facility that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy that the material is being furnished in accordance with this specification. All tests and inspection required by the specification, that are requested by the purchaser’s representative and purchase order, shall be made prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operations of the manufacturer.

18. Rejection and Rehearing

18.1 Material that fails to conform to the requirements of this specification shall be rejected. If rejection is made by the purchaser, it shall be reported to the supplier promptly in writing. In case of disagreement with the results of the tests or inspection performed or authorized by the purchaser, the supplier may make claim for a retesting or reinspection.

19. Certification and Test Reports

19.1 Certificate of Compliance—Unless otherwise specified in the purchase order, the manufacturer shall furnish certification that the product was manufactured and tested in accordance with this specification and the customer’s order and conforms to all specified requirements.

19.2 Test Reports—When specified on the purchase order, the manufacturer shall furnish a test report showing the chemical analysis of the material used to produce the fasteners and the results of the last completed set of mechanical tests, for each lot of fasteners in the shipment. Corrosion test results shall be reported when corrosion testing has been performed.

20. Product Marking

20.1 Individual Products—All products shall be marked with a symbol identifying the manufacturer. In addition, they shall be marked with the alloy/mechanical property marking in accordance with Table 2. The manufacturer may at its option add the specific alloy designation from Table 1. The marking shall be raised or depressed at the option of the manufacturer.

21. Packaging and Package Marking

21.1 Packaging:

21.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

21.1.2 When special packaging requirements are required by the purchaser, they shall be defined at the time of inquiry and order.

21.2 Package Marking—Each shipping unit shall include or be plainly marked with the following:

21.2.1 ASTM designation,
21.2.2 Alloy number,
21.2.3 Name of item (that is, bolt, hex cap screw, or stud),
21.2.4 Size,
21.2.5 Name and brand or trademark of the manufacturer,
21.2.6 Number of pieces,
21.2.7 Purchase order number, and
21.2.8 Lot number, if applicable.

22. Keywords

22.1 bolts; heat resistant; hex cap screws; high temperature; stainless steel; studs
SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry and order (see 5.2.6). Supplementary requirements shall in no way negate any requirements of the specification itself.

S1. Shipment Lot Testing

S1.1 When Supplementary Requirement S1 is specified on the order, the manufacturer shall make sample tests on the individual lots for shipment, to ensure that the product conforms to the specified requirements.

S1.2 The manufacturer shall make an analysis of a randomly selected finished fastener from each lot of product to be shipped. Heat or lot control shall be maintained. The analysis of the starting material from which the fasteners have been manufactured may be reported in place of the product analysis.

S1.3 The manufacturer shall perform mechanical property tests in accordance with this specification and Guide F 1470 on the individual lots for shipment.

S1.4 The manufacturer shall furnish a test report, for each lot in the shipment, showing the actual results of the chemical analysis, mechanical property tests performed, and if required corrosion testing results, in accordance with Supplementary Requirement S1.

S2. Additional Tests

S2.1 When additional tests of mechanical properties are desired by the purchaser, Supplementary Requirement S2 shall be specified on the inquiry and order. The additional test(s) shall be made, as agreed upon between the manufacturer and the purchaser, at the time of the inquiry or order.

S3. Source Inspection

S3.1 When Supplementary Requirement S3 is specified on the inquiry and order, the product shall be subject to inspection by the purchaser, at the place of manufacturer, prior to shipment.

S4. Heat Control

S4.1 When Supplementary Requirement S4 is specified on the inquiry and order, the manufacturer shall control the product by heat analysis and identify the finished product in each shipment by the actual heat number.

S4.2 When Supplementary Requirement S4 is specified on the inquiry and order, Supplementary Requirement S1 shall be considered automatically invoked, with the addition that the heat analysis shall be reported to the purchaser on the test reports.

S5. Permeability

S5.1 When Supplementary Requirement S5 is specified on the inquiry and order, the permeability of bolts, hex cap screws and studs of Type I Class A, Type II, and Type III Class A and B, in Condition A, Condition CWA, and Condition HWA, shall not exceed 1.5 at 100 oersteds when determined in accordance with Test Methods A 342/A 342M.

S6. Corrosion Resistance Tests

S6.1 When Supplementary Requirement S6 is specified on the inquiry and order, corrosion test(s) shall be performed, as agreed upon between the manufacturer and the purchaser, at the time of the inquiry or order.

S7. Passivation

S7.1 When supplementary Requirement S7 is specified on the inquiry and order, the finished product shall be passivated, in accordance with Specification A 380.

S8. High Temperature Tests

S8.1 When Supplementary Requirement S8 is specified on the inquiry and order, tests to determine high temperature properties shall be performed, in accordance with Practices E 21, E 139, and E 292, or other equivalent method. One high temperature test shall be performed on each lot at a test temperature agreed upon between the buyer and the seller and selected from one of the test temperatures listed in Table 3.
X1. GUIDE TO SERVICE APPLICATION

X1.1 This Guide should not be used as the sole criteria for selecting high temperature and heat resisting materials for fasteners. Corrosion, stress corrosion cracking, embrittlement, and deterioration are the ultimate responsibility of the user. (Warning—Prolonged exposure of Heat Resisting Alloys to temperatures from 700 to 1500°F (temperature sensitivity varies with the different grades) can result in chromium carbide precipitation, reduced corrosion resistance, reduced impact strength, or other embrittling phenomena.)

<table>
<thead>
<tr>
<th>TABLE X1.1 Guide to Service Application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type I, Class A Heat Resisting Alloys at Continuous Service</strong></td>
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<tr>
<td>Alloy Grade</td>
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<tr>
<td>304/304L</td>
</tr>
<tr>
<td>316/316L</td>
</tr>
<tr>
<td><strong>Type I, Class B Heat Resisting Alloys at Continuous Service</strong></td>
</tr>
<tr>
<td>Alloy Grade</td>
</tr>
<tr>
<td>410/416</td>
</tr>
<tr>
<td>431</td>
</tr>
<tr>
<td><strong>Type I, Class C Heat Resisting Alloys at Continuous Service</strong></td>
</tr>
<tr>
<td>Alloy Grade</td>
</tr>
<tr>
<td>430/430F</td>
</tr>
<tr>
<td><strong>Type II, Heat Resisting Alloys at Continuous Service and Intermittent Service</strong></td>
</tr>
<tr>
<td>Alloy Grade</td>
</tr>
<tr>
<td>309</td>
</tr>
<tr>
<td>310</td>
</tr>
<tr>
<td>321</td>
</tr>
<tr>
<td>330</td>
</tr>
<tr>
<td>347</td>
</tr>
<tr>
<td><strong>Type III, Class A Nickel Alloys for High Temperature Service</strong></td>
</tr>
<tr>
<td>Alloy Grade</td>
</tr>
<tr>
<td>600</td>
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<tr>
<td>601</td>
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<tr>
<td><strong>Type III, Class B Precipitation Hardened Alloys for High Temperature Service</strong></td>
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<tr>
<td>Alloy Grade</td>
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<tr>
<td>660</td>
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</table>
Standard Specification for
Quality Assurance Requirements for Carbon and Alloy Steel Wire, Rods, and Bars for Mechanical Fasteners

This standard is issued under the fixed designation F 2282; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification establishes quality assurance requirements for the physical, mechanical, and metallurgical requirements for carbon and alloy steel wire, rods, and bars in coils intended for the manufacture of mechanical fasteners which includes: bolts, nuts, rivets, screws, washers, and special parts manufactured cold.

Note 1—The Steel Industry uses the term “quality” to designate characteristics of a material which make it particularly well suited to a specific fabrication and/or application and does not imply “quality” in the usual sense.

1.2 Wire size range includes 0.062 to 1.375 in.
1.3 Rod size range usually includes 7/32 in. (0.219) to 47/64 in. (0.734) and generally offered in 1/64 increments (0.0156).
1.4 Bar size range includes 3/8 in. (0.375) to 1 1/2 in. (1.500).
1.5 Sizes for wire, rod and bar outside the ranges of paragraphs 1.2-1.4 may be ordered by agreement between purchaser and supplier.
1.6 Material is furnished in many application variations. The purchaser should advise the supplier regarding the manufacturing process and finished product application as appropriate. Five application variations are:

- Cold Heading
- Recessed Head
- Socket Head
- Scrapless Nut
- Tubular Rivet

1.6.1 Wire is furnished for all five application variations.
1.6.2 Rod and bar are furnished to the single application variation; Cold Heading.

2. Referenced Documents

2.1 ASTM Standards:
- A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought, and Cold-Finished, General Requirements
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 700 Practices for Packaging, Marking and Loading Methods for Steel Products for Domestic Shipment
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- E 4 Practices for Force Verification of Testing Machines
- E 10 Test Method for Brinell Hardness of Metallic Materials
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E 112 Test Methods for Determining Average Grain Size
- E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings
- E 407 Practice for Microetching Metals and Alloys
- E 1077 Test Methods for Estimating the Depth of Decarburization of Steel Specimens
- F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
- F 1789 Terminology of F16 Mechanical Fasteners

2.2 AIAG Standard:
- B-5 Primary Metals Tag Application Standard

2.3 IFI Standard:
- IFI-140 Carbon and Alloy Steel Wire, Rods, and Bars for Mechanical Fasteners

2.4 SAE Standards:
- J403 Chemical Compositions of SAE Carbon Steels
- J404 Chemical Compositions of SAE Alloy Steels
- J406 Methods of Determining Hardenability of Steels
- J415 Definitions of Heat Treating Terms

3. Terminology

3.1 Definitions:

3.1.1 annealing—a process of heating to and holding steel at a given temperature for a given time and then cooling at a given rate, used to soften or produce changes, or both, in the microstructure of the steel to enhance formability and reduce tensile strength.
3.1.2 bars—produced from hot rolled or cast billets or blooms rolled single strand into coils. Bars have a greater precision in cross section than rods. Size tolerances are in Table 1. Bars are finished as-rolled, annealed, or spheroidize annealed, and in sizes included in 1.4.

3.1.3 lap—a longitudinal surface discontinuity extending into rod, bar, or wire caused by doubling over of metal during hot rolling.

3.1.4 lot—a quantity of raw material of one size and heat number submitted for testing at one time.

3.1.5 rods—produced from hot rolled or cast billets, usually rolled in a multiple strand mill to a round cross section then coiled into one continuous length to size tolerances shown in Table 2. Rods are furnished as-rolled, annealed, or spheroidize annealed in sizes found in 1.3.

3.1.6 seam—a longitudinal discontinuity extending radially into wire, rod, or bar. Seams in raw material used for the manufacture of fasteners or formed parts may lead to the formation of bursts.

3.1.7 spheroidizing—a form of annealing, involves prolonged heating at temperatures near the lower critical temperature, followed by slow cooling, with the object of forming spheroidal metallic carbides that allow a higher degree of formability.

3.1.8 void—a shallow pocket or hollow on the surface of the material.

3.1.9 wire—produced from hot rolled or annealed rods or bars by cold drawing for the purpose of obtaining desired size, dimensional accuracy, surface finish, and mechanical properties. Wire is furnished in the following conditions: direct drawn (DD); drawn from annealed rod or bar (DFAR or DFAB); drawn from spheroidized annealed rod or bar (DFSR or DFSB); drawn to size and spheroidized (SAFS); drawn, annealed in process, and finally lightly drawn to size (AIP); and drawn, spheroidize annealed in process, and finally lightly drawn to size (SAIP). Wire size tolerances are shown in Table 3. Sizes include those specified in 1.2.

3.1.9.1 Discussion—Spheroidize annealed-at-finish size wire (SAFS) is wire that has been spheroidize annealed after final cold reduction. One or more annealing treatments may precede the final cold reduction.

3.1.9.2 Discussion—Annealed-in-Process (AIP) or Spheroidize Annealed-in-Process (SAIP) wire is produced as drawn carbon or alloy steel wire. In producing AIP and SAIP wire, rods or bars are drawn to wire and thermal treatment (followed by a separate cleaning and coating operation) is done prior to final drawing to produce a softer and more ductile wire for applications in which direct drawn wire would be too hard.

### TABLE 1 Bar Size Tolerances

<table>
<thead>
<tr>
<th>Fractional Diameter, in.</th>
<th>Diameter ± Tolerance, in.</th>
<th>Out of Round max, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4 to 5/8</td>
<td>0.006</td>
<td>0.009</td>
</tr>
<tr>
<td>&gt; 5/8 to 7/8</td>
<td>0.007</td>
<td>0.011</td>
</tr>
<tr>
<td>&gt; 7/8 to 1</td>
<td>0.008</td>
<td>0.012</td>
</tr>
<tr>
<td>&gt; 1 to 1 1/4</td>
<td>0.009</td>
<td>0.014</td>
</tr>
<tr>
<td>&gt; 1 1/4 to 1 1/8</td>
<td>0.010</td>
<td>0.015</td>
</tr>
<tr>
<td>&gt; 1 1/8 to 1 1/4</td>
<td>0.011</td>
<td>0.017</td>
</tr>
<tr>
<td>&gt; 1 1/8 to 1 1/2</td>
<td>0.013</td>
<td>0.020</td>
</tr>
</tbody>
</table>

### TABLE 2 Rod Size Tolerances

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 1 to 1 1/4</td>
<td>0.012</td>
<td>0.018</td>
</tr>
</tbody>
</table>

### TABLE 3 Wire Size Tolerances and Out of Round

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.706</td>
<td>0.0010</td>
<td>0.0010</td>
</tr>
<tr>
<td>0.706 to 0.500</td>
<td>0.0015</td>
<td>0.0015</td>
</tr>
<tr>
<td>≥ 0.500</td>
<td>0.0020</td>
<td>0.0020</td>
</tr>
</tbody>
</table>

Thermal treatment may also be employed when controlled mechanical properties are required for a specific application.

3.2 Heat treating terms not defined in this standard are included in Terminology F1789 or SAE J415.

### 4. Ordering Information

4.1 Wire orders shall state the following:

4.1.1 Quantity,

4.1.2 Specification number and issue date,

4.1.3 Diameter,

4.1.4 Steel grade,

4.1.5 Deoxidation practice and grain size or refinement practice (coarse or fine); see 5.3.1-5.3.5,

4.1.6 Application variation per 1.6,

4.1.7 Thermal treatment; see 5.5,

4.1.8 Surface coating,

4.1.9 Coil weight and dimensions as required,

4.1.10 Packaging,

4.1.11 Tagging,

4.1.12 Mill certification as required,

4.1.13 Special requirements, for example, steel making method and practice, specific hardenability, special shipping instructions, single heat, etc., and

4.1.14 Example—40 000 lb, ASTM F 2282, 0.250 in., carbon steel wire, IFI-1022A, silicon killed coarse grain, Recessed Head, spheroidize annealed-in-process, phosphate and lube, 1500 lb coils, 28 in. coil i.d., on 18 in. tubular carriers, three bands per carrier, one metal tag per coil, mill certification, do not ship Fridays.

4.2 Rod orders shall state the following:

4.2.1 Quantity,

4.2.2 Specification number and issue date,

4.2.3 Diameter,

4.2.4 Steel grade,

4.2.5 Deoxidation practice and grain size or refinement practice (coarse or fine),

4.2.6 Cold Heading,

4.2.7 Thermal treatment,

4.2.8 Surface coating,

4.2.9 Coil weight and dimensions as required,

4.2.10 Packaging,

4.2.11 Tagging,

4.2.12 Mill certifications as required,

4.2.13 Special requirements, for example, descaling practice, steelmaking method and practice, specific hardenability, special shipping instructions, etc., and
4.2.14 Example—200 000 lb, ASTM F 2282, 2\(\frac{3}{16}\) in., carbon steel rod, IFI-1022B, silicon killed fine grain, Cold Heading, spheroidize annealed, pickled and limed, 3000 lb coils, 48 in. coil i.d., compacted and unitized in packages of two, banded with three steel straps per coil, two metal tags per coil attached to lead end on inside of bundle, put separators between coils.

4.3 Bar orders shall state the following:

4.3.1 Quantity,
4.3.2 Specification number and issue date,
4.3.3 Diameter,
4.3.4 Steel grade,
4.3.5 Deoxidation practice and grain size or refinement practice (coarse or fine),
4.3.6 Cold Heading,
4.3.7 Thermal treatment,
4.3.8 Surface coating,
4.3.9 Coil weight and dimensions as required,
4.3.10 Packaging,
4.3.11 Tagging,
4.3.12 Mill certification as required,
4.3.13 Special requirements, for example, steelmaking method and practice, specific hardenability, special shipping instructions, single heat, etc., and

4.3.14 Example—90 000 lb, ASTM F 2282, 0.610 in., carbon steel bars, IFI-1038, silicon killed coarse grain, spheroidize annealed, Cold Heading, phosphate and lime, 5400 lb coils, 54 in. coil i.d., three bands per coil, one metal tag per coil, lead end of each coil paint red.

5. Manufacture

5.1 Melting Practice—The steel shall be melted in a basic oxygen or electric furnace process.

5.2 Casting Practice—Steel shall be ingot cast, or continuous cast with controlled procedures to meet the requirements of this specification.

5.3 Deoxidation Practice and Grain Size—The material shall be furnished in one of the deoxidation and grain size practices included in 5.3.1-5.3.5, as specified by the purchaser. When not specified, the practice shall be at the option of the manufacturer.

5.3.1 Silicon killed fine grain shall be produced with aluminum for grain refinement. The material purchaser’s approval shall be obtained for the use of vanadium or columbium for grain refinement.

5.3.2 Silicon killed coarse grain practice.
5.3.3 Silicon killed fine grain practice.
5.3.4 Aluminum killed fine grain practice.
5.3.5 Rimmed (grain size not specified).

5.4 Hardenability:

5.4.1 Hardenability for steels with a specified minimum carbon content of 0.20 % or greater shall be determined for each heat and the results furnished to the purchaser when requested on the purchase order. SAE J406, Appendix A shall be used for referee purposes in the event of dispute.

5.5 Thermal Treatments:

5.5.1 The purchaser shall specify one of the following options for thermal treatment on the purchase order:
5.5.1.1 No thermal treatment.
5.5.1.2 Annealed.
5.5.1.3 Spheroidized.
5.5.1.4 Drawn from annealed rod or bar.
5.5.1.5 Drawn from spheroidize annealed rod or bar.
5.5.1.6 Spheroidized at finished size wire.
5.5.1.7 Annealed-in-process wire.
5.5.1.8 Spheroidized annealed-in-process wire.

6. Chemical Requirements

6.1 The material shall have a chemical composition conforming to the requirements specified in Tables 4-8 for the applicable IFI grade specified by the material purchaser.

**Note:** The chemical compositions have been developed in a joint producer/user effort and are particularly appropriate to the cold forging industry process. The chemical composition ranges of these IFI grades may not be identical to those of SAE J403, SAE J404, or AISI.

### Table 4: Carbon Steels, Chemical Ranges and Limits, %

<table>
<thead>
<tr>
<th>Conditions Furnished</th>
<th>IFI Steel Grade Designation</th>
<th>Carbon</th>
<th>Manganese</th>
<th>Phosphorous Max</th>
<th>Sulfur Max</th>
<th>Silicon Max</th>
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</thead>
<tbody>
<tr>
<td>R, AlK</td>
<td>IFI-1006</td>
<td>. . .</td>
<td>.08</td>
<td>.25</td>
<td>.40</td>
<td>.020</td>
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<tr>
<td>R, AlK, SiFg, SiCg</td>
<td>IFI-1008</td>
<td>. . .</td>
<td>.10</td>
<td>.30</td>
<td>.50</td>
<td>.020</td>
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<tr>
<td>R, AlK, SiFg, SiCg</td>
<td>IFI-1010</td>
<td>.08</td>
<td>.13</td>
<td>.30</td>
<td>.60</td>
<td>.020</td>
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<tr>
<td>AlK, SiFg</td>
<td>IFI-1018</td>
<td>.15</td>
<td>.19</td>
<td>.65</td>
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<td>.020</td>
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<tr>
<td>AlK, SiFg, SiCg</td>
<td>IFI-1021</td>
<td>.19</td>
<td>.23</td>
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<td>AlK, SiFg, SiCg</td>
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<td>AlK, SiFg, SiCg</td>
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<td>.20</td>
<td>.23</td>
<td>.90</td>
<td>1.10</td>
<td>.020</td>
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<td>AlK</td>
<td>IFI-1033</td>
<td>.31</td>
<td>.36</td>
<td>.70</td>
<td>0.90</td>
<td>.020</td>
</tr>
<tr>
<td>AlK, SiFg, SiCg</td>
<td>IFI-1035</td>
<td>.33</td>
<td>.38</td>
<td>.70</td>
<td>0.90</td>
<td>.020</td>
</tr>
<tr>
<td>AlK, SiFg, SiCg</td>
<td>IFI-1038</td>
<td>.35</td>
<td>.42</td>
<td>.70</td>
<td>0.90</td>
<td>.020</td>
</tr>
<tr>
<td>SiFg</td>
<td>IFI-10838</td>
<td>.35</td>
<td>.42</td>
<td>.70</td>
<td>1.00</td>
<td>.020</td>
</tr>
<tr>
<td>SiFg, SiCg, CgP</td>
<td>IFI-1541/A</td>
<td>.36</td>
<td>.41</td>
<td>1.35</td>
<td>1.60</td>
<td>.020</td>
</tr>
<tr>
<td>SiFg, SiCg, CgP</td>
<td>IFI-1541/B</td>
<td>.38</td>
<td>.43</td>
<td>1.35</td>
<td>1.60</td>
<td>.020</td>
</tr>
</tbody>
</table>

**Note:**—Carbon steels which have added boron use a B designation between the first and last two digits of the grade designation. A boron steel has a minimum boron content of 0.0008 % and a maximum of 0.003 % together with a minimum titanium content of 0.01 %.

AlK = Aluminum killed
R = Rimmed
SiFg = Silicon killed fine grain
SiCg = Silicon killed coarse grain
CgP = Coarse grain practice
6.4.2 Rimmed or capped steels are characterized by a lack of uniformity in their chemical composition, especially for the elements carbon, phosphorus, and sulfur, and for this reason product analysis is not technologically appropriate unless misapplication is clearly indicated.

6.4.3 Test Methods A 751 shall be used.

6.5 Residual Element Limits—Material grades defined in this standard shall conform to the residual element limits in Table 9.

7. Metallurgical Structure

7.1 Coarse Austenitic Grain Size:

7.1.1 When a coarse grain size is specified, the steel shall have a grain size number of 1 to 5 inclusive.

7.1.2 Conformance to this grain size of 70 % of the grains in the area examined shall constitute the basis of acceptance.

7.2 Fine Austenitic Grain Size:

7.2.1 When a fine grain size is specified, the steel shall have a grain size number greater than five, as determined in accordance with Test Methods E 112.

7.2.2 Conformance to this grain size of 70 % of the grains in the area examined shall constitute the basis of acceptance.

7.2.3 When aluminum is used as the grain refining element, the fine austenitic grain size requirement shall be deemed to be fulfilled if, on heat analysis, the total aluminum content is not less than 0.020 % total aluminum or, alternately, 0.015 % acid soluble aluminum. The aluminum content shall be reported. The grain size test specified in 7.2.1 shall be the referee test.

7.2.4 If columbium or vanadium or both are to be used, Supplementary Requirement S.2 shall be specified.

7.2.5 If specified on the order, one grain size test per heat shall be made and the austenitic grain size of the steel, as represented by the test, shall be number 6 or higher.

7.3 Spheroidized Annealed Materials:

7.3.1 Spheroidize annealed material shall meet a minimum test rating of G2 or L2 in the IFI spheroidization rating—Plate 1 (see Fig. 1).

7.3.2 Optimum spheroidization is equal to or greater than 90 %. The spheroidization rating shall be performed on a polished transverse sample etched with a 2 % Nital solution in accordance with Practice E 407. The examination area for spheroidization shall be at or near the center of the material. The resulting structure shall be compared at 1000× magnification to Plate 1. The following descriptions may be used to better compare to Plate 1.

<table>
<thead>
<tr>
<th>Spheroidization Rating Descriptions for Plate 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
</tr>
<tr>
<td>Description</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>Spheroidal carbides are homogeneously distributed in a matrix of ferrite.</td>
</tr>
<tr>
<td>80 G1/L1</td>
</tr>
<tr>
<td>All carbides are spheroidal with a good distribution. Grain boundaries are not so obvious.</td>
</tr>
<tr>
<td>60 G2/L2</td>
</tr>
<tr>
<td>Most of the carbides are spheroidal with an average distribution. Some lamellar carbides and grain boundaries are present.</td>
</tr>
<tr>
<td>40 G3/L3</td>
</tr>
<tr>
<td>Approximately 1/2 of the carbides have been spheroidized. All carbides are in prior pearlitic colonies; grain boundaries are prevalent.</td>
</tr>
<tr>
<td>20 G4/L4</td>
</tr>
<tr>
<td>A very slight breakup of the lamellar carbides; mainly pearlite and ferrite.</td>
</tr>
<tr>
<td>0 G5/L5</td>
</tr>
<tr>
<td>The entire microstructure consists of pearlite and ferrite.</td>
</tr>
</tbody>
</table>

### Table 5 Permissible Variations from Specified Chemical Ranges, and Limits for Carbon Steel, %

<table>
<thead>
<tr>
<th>Element</th>
<th>Limit or Max of Specified Range, %</th>
<th>Variation % Over Max Limit or Under Min Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>To 0.25 incl</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Over 0.25 to 0.55 incl</td>
<td>0.03</td>
</tr>
<tr>
<td>Manganese</td>
<td>To 0.90 incl</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Over 0.90 to 1.65 incl</td>
<td>0.06</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Over max only</td>
<td>0.008</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Over max only</td>
<td>0.008</td>
</tr>
<tr>
<td>Silicon</td>
<td>To 0.30 incl</td>
<td>0.02</td>
</tr>
<tr>
<td>Copper</td>
<td>Over max only</td>
<td>0.03</td>
</tr>
<tr>
<td>Tin</td>
<td>Over max only</td>
<td>0.01</td>
</tr>
<tr>
<td>Nickel</td>
<td>Over max only</td>
<td>0.03</td>
</tr>
<tr>
<td>Chromium</td>
<td>Over max only</td>
<td>0.03</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Over max only</td>
<td>0.01</td>
</tr>
<tr>
<td>Vanadium</td>
<td>Over max only</td>
<td>0.01</td>
</tr>
<tr>
<td>Boron</td>
<td>N/A^A</td>
<td></td>
</tr>
</tbody>
</table>

^A Unless misapplication is indicated.

### Table 6 Silicon Limits for Four Deoxidation Practices, %

<table>
<thead>
<tr>
<th>Deoxidation Practice</th>
<th>Silicon Killed</th>
<th>Silicon Killed</th>
<th>Aluminum Killed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine Grain</td>
<td>Min Max</td>
<td>Min Max</td>
<td>Min Max</td>
</tr>
<tr>
<td>Course Grain</td>
<td>100 0.10 0.20</td>
<td>100 0.10 0.25</td>
<td>100 0.10 0.02</td>
</tr>
<tr>
<td>and Course Grain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practice</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boron Grades</td>
<td>100 0.15 0.30</td>
<td>N/A N/A</td>
<td>N/A N/A</td>
</tr>
<tr>
<td>All Other Grades</td>
<td>0.15 0.30</td>
<td>0.15 0.30</td>
<td>0.10 0.10</td>
</tr>
</tbody>
</table>

Note 1—Fine Grain—Normally Si/Al killed or aluminum killed. Vanadium or Columbian (niobium) can be used upon agreement between raw material supplier and user (purchaser). See Supplementary Requirement S.2.

Note 2—The values listed in this table are designed to provide optimum headability and tool life in the cold forming process. Modificitations to these limits require agreement between producer and purchaser.
8. Decarburization

8.1 The entire periphery of a sample prepared of the rod, wire, or bar for killed steels having carbon content exceeding 0.15 % shall be examined for decarburization at a magnification of 100 diameters. Free ferrite shall not exceed the maximum depth as specified in Table 10. The worst location shall be used to draw perpendicular bisectors, and the depth of decarb at the points where the bisectors intersect the circumference, shall be measured and the four (4) readings averaged as defined in the example identified as Fig. 2.

8.2 That average shall not exceed the limits for total average affected depth (TAAD) as specified in Table 10. The depth (D) of the worst location shall not exceed the maximum allowed in Table 10.

9. Mechanical Properties

9.1 Bars, rod, and wire furnished in the conditions below shall conform to the tensile strength and reduction in area requirements specified in Table 11.

9.1.1 Annealed or spheroidize annealed rod and bar.
9.1.2 Spheroidize annealed at finish size wire.
9.1.3 Annealed-in-process or spheroidize annealed-in-process wire.

9.2 Percent reduction in area is determined by the test methods of Test Methods A 370. Values for minimum percentages which shall apply are included in Table 11.

9.3 No individual test value shall be out of specification, and for steels with a maximum specified carbon content over 0.30 %, the maximum range shall not exceed the minimum by more than 10 % in any lot; for example:

\[
\begin{align*}
80 \text{ KSI} & \text{ accept} \\
74 \text{ KSI} & \text{ reject}
\end{align*}
\]

9.4 Tensile/reduction in area equipment shall be calibrated and verified in accordance with Practices E 4, and operated by personnel with documented qualifications.

9.5 Conformance of all test data shall be determined in accordance with Practice E 29.

10. Dimensional Size Tolerances

10.1 Wire tolerances are shown in Table 3.
10.2 Rod tolerances are shown in Table 2.

NOTE 4—Inherent mill design of rod mills does not permit the same control of size as bar mills. Reducing diameter variability increases control of both the physical and mechanical properties during the forming process. Less variability permits engineering for reduced tool wear and consistent product quality.

10.3 Bar tolerances are shown in Table 1.

11. Mill Scale/Surface Condition

11.1 Mill scale (surface oxides) on hot rolled material shall be readily removable by an acid pickling or mechanical descaling process.

11.2 The surface shall be free from excessive dirt contaminants or rust which would impede pickling or descaling, or contaminate an acid pickle bath.

12. Coatings

12.1 The supplied coatings shall be specified for all materials by the purchaser based upon the individual requirements of the purchaser. Adequate care should be taken during handling and transit to maintain the integrity of the coating.

### TABLE 7 Chemical Ranges and Limits for Alloy Steels, %

<table>
<thead>
<tr>
<th>IFI Steel Grade Designation</th>
<th>Carbon</th>
<th>Manganese</th>
<th>Nickel</th>
<th>Chromium</th>
<th>Molybdenum</th>
<th>Phosphorous</th>
<th>Sulfur</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Min</td>
<td>Max</td>
<td>Min</td>
<td>Max</td>
<td>Max</td>
</tr>
<tr>
<td>IFI-1335</td>
<td>0.33</td>
<td>0.38</td>
<td>1.60</td>
<td>1.90</td>
<td>.</td>
<td>.</td>
<td>0.020</td>
</tr>
<tr>
<td>IFI-4037a</td>
<td>0.35</td>
<td>0.40</td>
<td>0.70</td>
<td>0.90</td>
<td>.</td>
<td>.</td>
<td>0.20</td>
</tr>
<tr>
<td>IFI-4042</td>
<td>0.40</td>
<td>0.45</td>
<td>0.70</td>
<td>0.90</td>
<td>.</td>
<td>.</td>
<td>0.30</td>
</tr>
<tr>
<td>IFI-4118</td>
<td>0.18</td>
<td>0.23</td>
<td>0.75</td>
<td>0.90</td>
<td>.</td>
<td>.</td>
<td>0.60</td>
</tr>
<tr>
<td>IFI-4140</td>
<td>0.38</td>
<td>0.43</td>
<td>0.75</td>
<td>1.00</td>
<td>.</td>
<td>.</td>
<td>1.10</td>
</tr>
<tr>
<td>IFI-5140</td>
<td>0.38</td>
<td>0.43</td>
<td>0.70</td>
<td>0.90</td>
<td>.</td>
<td>.</td>
<td>0.90</td>
</tr>
<tr>
<td>IFI-8637</td>
<td>0.35</td>
<td>0.40</td>
<td>0.70</td>
<td>0.90</td>
<td>0.10</td>
<td>0.15</td>
<td>0.25</td>
</tr>
</tbody>
</table>

a Furnished in AlK or SiFg or SiCg or CgP. All other grades in SiFg-Fg only.

### TABLE 8 Permissible Variation from Specified Chemical Ranges and Limits for Alloy Steels, %

<table>
<thead>
<tr>
<th>Element</th>
<th>Limit or Max of Specified Range, %</th>
<th>Variation, %, Over Max Limit or Under Min Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>To 0.30 incl</td>
<td>0.01</td>
</tr>
<tr>
<td>Manganese</td>
<td>Over 0.30 to 0.75 incl</td>
<td>0.02</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Over Max only</td>
<td>0.005</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Over Max only</td>
<td>0.005</td>
</tr>
<tr>
<td>Silicon</td>
<td>To 0.40 incl</td>
<td>0.02</td>
</tr>
<tr>
<td>Nickel</td>
<td>To 1.00 incl</td>
<td>0.03</td>
</tr>
<tr>
<td>Chromium</td>
<td>Over 0.90</td>
<td>0.05</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Over 0.20</td>
<td>0.01</td>
</tr>
<tr>
<td>Vanadium</td>
<td>Over Max only</td>
<td>0.01</td>
</tr>
</tbody>
</table>

### TABLE 9 Residual Element Limits

<table>
<thead>
<tr>
<th>Element</th>
<th>Residual Limit, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>0.20</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.10</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.10</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.04</td>
</tr>
<tr>
<td>Tin</td>
<td>0.02</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.009</td>
</tr>
<tr>
<td>Boron</td>
<td>0.0007</td>
</tr>
</tbody>
</table>

a Residual limits for a given element do not apply to alloy steel if that element has a specified range.

b Controlling residual limits provides optimum formability and tool life during cold forming operations.

c See Supplementary Requirements.

d Not applicable to boron steels (see Table 4). Titanium shall not exceed 0.01 % for steels which do not have an intentional addition of boron and titanium.
Extreme variations in temperature and humidity may adversely affect the applied coatings.

12.2 Coatings for hot rolled bars, wire rods, and wire which are thermally treated at finished size include the following:
12.2.1 Pickle and lime dip,
12.2.2 Zinc phosphate and lime dip,
12.2.3 Zinc phosphate and reactive or nonreactive lube dip, and
12.2.4 Alternate coatings, including polymer, may be used upon agreement between purchaser and producer.

12.3 In addition, if cold drawing is the final operation, a drawing compound will also be applied through the die drawing process. There are, however, no batch coatings applied after drawing when cold drawing is the final operation.

13. Workmanship, Finish and Appearance

13.1 Bar, rod, and wire shall be free from detrimental surface imperfections including seams, voids, pits, scratches, and laps. Material, suitably thermally treated when appropriate, which bursts or splits when upset or formed, and having imperfections deeper than the greater of 0.003 in. or 0.5 % of D (where D is finished diameter in inches of material) shall be subject to rejection. Samples requiring assessment of such surface imperfections shall be prepared by metallographic
technique, suitably etched and the depth of imperfection measured radially from the surface at a magnification of 100×.

13.2 Wire shall not be kinked or tangled, and for wire drawn last, shall be properly cast. No welds are permitted, unless otherwise specified.

14. Number of Tests and Retests

14.1 Metallurgical:
14.1.1 Austenitic grain size shall be based on one test per heat in accordance with 7.2.4.

14.1.2 Each spheroidize annealed lot shall be tested once and shall meet minimum rating requirements of G2 or L2 (see 7.3.1).

14.1.3 For each lot of wire, rod, or bar, a single sample shall be tested for decarburization in accordance with Section 8 of this standard.

14.2 Mechanical:
14.2.1 Rods, bars, and wire shall be tested one sample per coil/bundle on at least 20% of randomly selected coils/bundles in the lot with at least two tests for maximum tensile strength.
14.2.2 Rods, bars, and wire shall be tested one sample per coil/bundle on at least 20% of randomly selected coils/bundles in the lot with at least two tests for percent reduction in area.

14.2.3 Yield strength, percent elongation, and hardness tests are included in supplementary requirements of this standard.

15. Test Methods

15.1 Maximum Tensile Strength:
15.1.1 Maximum tensile strength shall be determined in accordance with the test methods of Test Methods A 370.

15.2 Reduction of Area:
15.2.1 Reduction of area is determined by test methods included within Test Methods A 370.

15.3 Calibration:
15.3.1 Tensile/reduction in area equipment shall be calibrated in accordance with Practices E 4.

15.4 Hardenability:
15.4.1 Hardenability shall be determined in accordance with SAE J406, Appendix A or B.

15.5 Grain Size:
15.5.1 Grain Size shall be determined in accordance with Test Method E 112.

15.6 Decarburization:
15.6.1 Decarburization shall be determined using the test method Test Methods E 1077.

15.7 Control of Measuring and Testing Equipment:
15.7.1 Unless otherwise specified, control shall conform to Guide F 1470.

16. Disposition of Nonconforming Lots

16.1 A recommended procedure for disposition of nonconforming lots may be found in Guide F 1470.

17. Identification/Tagging

17.1 A tag(s) shall be attached to each coil or banding as specified by the purchaser and shall include as a minimum the following information:
17.1.1 Supplier’s name or trademark,
17.1.2 Grade of steel,
17.1.3 Heat number or traceable code, and
17.1.4 Diameter.

17.2 When specified, the following may be added:
17.2.1 Purchaser’s name,
17.2.2 Purchase order number,
17.2.3 Mill order number,
17.2.4 Secondary process description and source if applicable, and
17.2.5 Bar coding (optional). It is suggested that bar coding in accordance with AIAG B-5 be used.

18. Packaging and Loading

18.1 Unless otherwise specified, rod coils shall be wound counterclockwise which provides a right hand pitch to facilitate handling and uncoiling. Winding of bar coils varies and the direction of winding should be specified. The nature of compacting, banding, and protection, shall be specified by purchaser.

18.2 The purchaser shall specify the method of packaging and loading for shipment. A recommended procedure for packaging and loading for shipment is found in Practices A 700.

19. Certification and Test Reports

19.1 When specified in the purchase order, a producer’s certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements as specified. Test results shall be retained by the producer in accordance with his quality assurance procedures. If requested by the purchaser, a test report shall be furnished which will meet the consumer’s requirements for chemical analysis of the mill heat including the identification and the results of the chemical analysis of the primary steel melter and austenitic grain size, if required.

19.2 Traceability shall include the mill order and steel heat number with all specified mechanical data on mill test certification.

20. Keywords

20.1 carbon and alloy steel; mechanical fasteners; quality assurance; wire, rods, and bars

TABLE 10 Decarburization Limits for Killed Steels With Carbon Content Exceeding 0.15 %

<table>
<thead>
<tr>
<th>Diameter, in.</th>
<th>Free Ferrite Depth max, in.</th>
<th>Total Average Affected Depth (TAAD) max, in.</th>
<th>Worst Location Depth, max, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>through 5/64</td>
<td>0.001</td>
<td>0.005</td>
<td>0.008</td>
</tr>
<tr>
<td>over 5/64</td>
<td>0.001</td>
<td>0.006</td>
<td>0.009</td>
</tr>
<tr>
<td>through 5/8</td>
<td>0.001</td>
<td>0.007</td>
<td>0.011</td>
</tr>
<tr>
<td>over 5/8</td>
<td>0.001</td>
<td>0.008</td>
<td>0.012</td>
</tr>
<tr>
<td>through 55/64</td>
<td>0.001</td>
<td>0.010</td>
<td>0.015</td>
</tr>
<tr>
<td>over 55/64</td>
<td>0.001</td>
<td>0.010</td>
<td>0.015</td>
</tr>
<tr>
<td>through 1</td>
<td>0.001</td>
<td>0.010</td>
<td>0.015</td>
</tr>
</tbody>
</table>

NOTE—Test conducted in accordance with Section 8 of this standard.
SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order.

S1. Residual Element Limits

S1.1 The residual limit for Cr shall be to 0.20 max if specified by the purchaser. The residual element limit for Mo may be to 0.06 max if so specified by the purchaser. Reduced residual element limits below those specified in Table 9 shall be based upon agreement between supplier and purchaser.

S2. Grain Refiners

S2.1 Use of columbium (Cb) or vanadium (V), or both, instead of or with aluminum shall be based on the requirements of Specification A 29/A 29M, paragraphs 5.1.2.2 and 5.1.2.3. For the convenience of the users of this standard, they are reprinted as follows:

"ASTM A 29/A 29M-99e1

5.1.2.2 By agreement between purchaser and supplier, columbium or vanadium or both may be used for grain refining instead of or with aluminum. When columbium or vanadium is used as a grain refining element, the fine austenitic grain size requirement shall be deemed to be fulfilled if, on heat analysis, the columbium or vanadium content is as follows (the content of the elements shall be reported with the heat analysis):

Steel having 0.25 % carbon or less:
Cb 0.025 min
V 0.05 min

Steel having over 0.25 % carbon:
Cb 0.015 min
V 0.02 min

The maximum contents shall be:
Cb 0.05 max
V 0.08 max
Cb + V 0.06 max

5.1.2.3 When provisions of 5.1.2.1 or 5.1.2.2 are exercised, a grain size test is not required unless specified by the purchaser. Unless otherwise specified, fine austenitic grain size shall be certified using the analysis of grain refining element(s)."

S3. Yield Strength/Percent Elongation

S3.1 Yield strength/percent elongation may be used for special applications when agreed upon between purchaser and supplier but are not required unless specified by the purchaser.

Note—The values in this table have been designed to provide optimum headability and tool life in the cold forming process. The reduction of area test is not applicable to wire sizes less than 0.092 in.

### TABLE 11 Mechanical Properties Carbon and Alloy Steels

<table>
<thead>
<tr>
<th>Steel Grade</th>
<th>Rod/Bar Properties</th>
<th>Spheroidize Annealed at Finished Size Wire Properties</th>
<th>Annealed in Process and Spheroidized Annealed in Process Finished Wire Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max Tensile&lt;sup&gt;A&lt;/sup&gt; KSI</td>
<td>Min R/A %</td>
<td>Max Tensile&lt;sup&gt;A&lt;/sup&gt; KSI</td>
</tr>
<tr>
<td>Carbon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IFI-1006</td>
<td>55</td>
<td>62</td>
<td>53</td>
</tr>
<tr>
<td>IFI-1008</td>
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<sup>A</sup> For aluminum killed steel, subtract 3 KSI and add 1 % R/A.
For rimmed steel, subtract 5 KSI and add 2 % R/A.
For AIP and SAIP wire under 0.200 in., add 50 psi for every 0.001 in. under 0.200 in.

Note—The values in this table have been designed to provide optimum headability and tool life in the cold forming process. The reduction of area test is not applicable to wire sizes less than 0.092 in.
manufacturer. Method of determination shall be in accordance with Test Methods A 370.

S4. Hardness

S4.1 Hardness may be used as an option when agreed to between producer and purchaser in lieu of tensile/reduction of area testing of wire or bar over 1 in. in diameter. Test method shall be in accordance with Test Method E 10.

S5. Mac-etch Test

S5.1 Mac-etch test may be used for bars when specified by the purchaser at the time of order. The test method shall be in accordance with Practice E 407 or Method E 381.

APPENDIXES

(Nonmandatory Information)

X1. HISTORY

X1.1 This ASTM standard is based on IFI-140, which was developed by the IFI Raw Materials Study Committee which is a joint effort of cooperation between the fastener manufacturer, the raw material manufacturer, and other important fastener industry suppliers.

X1.2 Following IFI approvals and subsequent publication, and in its traditional role of issuing IFI standards, it was intended that IFI-140 be introduced into the National Consensus Standards process of ASTM.

X2. MATERIALS AND PROCESSING

X2.1 Forming is the primary manufacturing operation in the fastener industry and the term includes heading, upsetting, extruding, and forging. These formed parts are produced at very high speeds by metal flow due to machine-applied pressure. The primary forming operation self-inspects the quality of the raw material and imperfections such as seams, laps, and internal pipe which may not be visible are revealed when the material is upset. The absence of bursts, forging cracks, and open seams is strong evidence that the quality of material selected was that intended for the severe upsets of today’s fastener manufacturing.

X2.2 Rods and Bars:

X2.2.1 While standard steel grades for rods and bars have been in existence for many years, and have, with modifications or restrictions of one or more elements, long been used for cold forming, this ASTM standard presents a distinct selected series of twenty steel grades for cold forming. These have been jointly developed by steel producers and cold heading and forging users under the aegis of the Industrial Fasteners Institute. These twenty grades are designated IFI steel grades and the ranges and limits for the thirteen carbon steel grades for carbon, manganese, phosphorus, and sulfur are shown in Table 4. Maximum residual limits for copper, nickel, chromium, molybdenum, and tin are specified in 6.5. Silicon ranges and limits are shown in Table 6. The chemical limits for the seven alloy steel grades are shown in Table 7.

X2.2.2 A significant area of improvement is in the decarburization control and measurement for cold heading rods and bars. A method to measure based upon the location of the worst decarburization position is described in Section 8 and shown in Fig. 2. The average total affected depth which may not be exceeded is found in Table 10. Free ferrite should not exceed the maximum depth of free ferrite at the worst location.

X2.2.3 To prepare a material for cold forming it is often spheroidized, which is an annealing treatment that transforms the microstructure of steel to its softest condition with maximum formability. In the hot rolled or normalized condition, steels containing less than 0.80% carbon consist of the microconstituents pearlite and ferrite. Pearlite, the harder of the two constituents, causes the steels to resist deformation. The harder pearlite is comprised of alternating thin layers or shells of ferrite and cementite (iron carbide), a very hard substance. In spheroidize annealing, the cementite layers are caused by time and temperature to collapse into spheroids or globules of cementite. This globular form of cementite tends to facilitate cold deformation in such processes as cold heading, cold rolling, forming, and bending.

X2.2.4 Plate 1, Fig. 1 displays variations in the transformation of pearlite to spheroidized cementite. Temperature variations within a charge or inadvertent heating either slightly below or slightly above the optimum temperature may produce a departure from the ideally spheroidized structure. Plate 1 displays material treated at a lower than ideal temperature exhibiting a granular structure and is shown as G1 through G5. Material treated at a higher than ideal temperature will exhibit a lamellar structure and is shown as L1 through L5. Latent energy from cold work will allow drawn wire to transform more readily to a higher degree of spheroidization than will hot rolled rod or bar. The degree of spheroidization is normally evaluated at 1000× magnification.

X2.2.5 When spheroidize annealed, Cold Heading Rods or Cold Heading Bars shall meet a maximum rating of G-2 or L-2 in Plate 1.
X2.2.6 While a fully spheroidized microstructure is desired for forming, material is rarely used in the “as spheroidized annealed” condition. Such material can cause processing difficulties because of its poor coil configuration, the formation of a “shear lip” during shearing, or result in undesirable bending of the fastener shank during cold heading. For these reasons almost all material is given a light wire drawing reduction after the thermal treatment either by the wire producer or in front of the fastener heading operation. Spheroidized structures are also known to retard austenization during short cycle heating, such as induction heating, in a subsequent hardening operation. Additional time may be required to dissolve the spheroidized cementite into the austenite at the heating temperature.

X2.2.7 The tolerances for rod and bar are reduced for IFI grades, reflecting the committee consensus that this feature would significantly improve control of cold working. Out-of-round material may cause localized die wear showing up as wear rings in the drawing die. The elliptical material cross section produces nonuniform cold work stresses around the circumference of the drawn cross section which contributes to distortion of the product and causes hardness variation across the section. Thus, serious efforts are anticipated now and in the future to bring about reasonable economic tolerance improvement.

X2.2.8 Rods and bars are subject to mill testing and inspection to provide material soundness and freedom from detrimental surface imperfections. These features are required to assure satisfactory performance of the wire produced from rods and bars. Thermal treatment as a part of wire mill processing is very important in the higher carbon grades of steel. Wire “direct drawn” from low carbon and medium low carbon steel wire rods is sometimes successfully used for simple two-blown upsetting or for standard trimmed hexagon head cap screws.

X2.2.9 As upsetting becomes progressively more demanding, wire drawn from annealed or spheroidize annealed rods is more appropriate. For demanding applications, annealed-in-process or spheroidize annealed-in-process wire is required. For thermally treated in-process wire, the final drawing operation may be performed by the wire supplier or incorporated into the cold heading operation by drawing in tandem with that operation.

X2.2.10 Cold Heading Rods and Bars will not necessarily result in successful production of recess head and socket head quality wire. Wire mills desiring to produce recess head and socket head wire should consult steel manufacturers to secure material with additional restrictive requirements.

X2.2.11 In the production of rods for heading, forging or cold extrusion in killed steels over 0.13% carbon, both austenitic grain size and decarburization are important features. Such steels can be produced either “fine” or “coarse” austenitic grain as required depending upon the type of heat treatment and application. Table 10 shows decarburization limits for the maximum permissible depth of free ferrite and the average total affected depth of decarburization. The examination is conducted as outlined in Section 8 of this standard. If decarburization limits closer than those shown in Table 10 are required in a given manufactured product, it is sometimes appropriate for the purchaser to incorporate means for carbon restoration in his manufacturing process.

X2.2.12 In cases of disagreement in the testing for decarburization, it is customary to make heat treatment tests of the finished product to determine suitability for the particular application.

X2.2.13 Rods and bars should be reasonably free from detrimental surface imperfections including seams, voids, pits, scratches, and laps. Material suitably thermally treated when appropriate, which bursts or splits when upset or formed, and having imperfections deeper than the greater of 0.003 in. or 0.5% of D (where D is the finished diameter in inches of material), is normally rejectable.

X2.2.14 Samples requiring assessment of such surface imperfections shall be prepared by careful metallographic technique, suitably etched, and the depth of imperfection measured radially from the surface at a magnification of 100×.

X2.2.15 Mechanical properties for thermally treated rods and bars are shown in Table 11.

X2.2.16 Rod size tolerances are shown in Table 2.

X2.2.17 Bar size tolerances are shown in Table 1.

X2.2.18 A selected series of steel grades has been developed for carbon steel rods and bars for cold heading and cold forging. See Table 4.

X2.3 Wire:

X2.3.1 Wire for cold heading and forging is produced from bars or rods featuring closer than normal control of chemical composition, size tolerances, decarburization limits, freedom from detrimental surface imperfections, and when appropriate, specified mechanical properties for thermally treated material, see Table 11; and when spheroidized, a maximum rating G2 or L2, see Plate 1.

X2.3.2 Thermal treatment of wire involves heating and cooling the steel in such a manner to achieve desired properties or structures.

X2.3.3 Annealing is the general term applied to a variety of thermal treatments for the purpose of softening the wire. Annealing commonly involves heating the material to temperature near or below the critical temperature. A number of processes are employed which influence the surface finish obtained. If a particular finish is required on wire annealed at final size, the producer should be consulted.

X2.3.4 Regular Annealing, sometimes called pot annealing, is performed by heating coils of wire in a furnace followed by slow cooling without an attempt to produce a specific microstructure or a specific surface finish.

X2.3.5 Spheroidize Annealing involves prolonged heating at a temperature near or slightly below the lower critical temperature, followed by slow cooling, with the object of producing a globular (spheroidal) condition of the carbide to obtain maximum softness.

X2.3.6 Annealed in Process Wire is a term normally associated with cold heading wire. The product is manufactured by drawing rod or bar to a size larger than the finished diameter wire, and regular annealing to relieve the stresses of cold work and obtain softening. This is followed by cleaning, coating with a suitable lubricant, and redrawing to finished size, usually with an area reduction of between 7% to 20%
depending upon wire size and application. See Table 11 for expected tensile strengths.

X2.3.7 Spheroidize Annealed in Process Wire is another term normally associated with cold heading wire. The product is manufactured by drawing rod to a size larger than the finished diameter wire, followed by spheroidize annealing to obtain maximum softness and to create a spheroidal structure as shown in Plate 1. The wire is then cleaned, coated with a suitable lubricant, and redrawn to finished size, usually with an area reduction of between 7 % to 20 % depending upon wire size and application.

X2.3.8 Decarburization Tests are made by the microscopic method described in Section 8. Table 10 shows the decarburization limits for the maximum depth of free ferrite and the maximum average total affected depth. The limits shown apply to wire made from killed steel over 0.13 % carbon. When closer limits are required, it is sometimes appropriate for the purchaser to incorporate means for carbon restoration in its finished product.

X2.3.9 Finishes or coatings are designed to provide proper lubrication for the header dies. With modern developments in cold heading technique, the role of wire finishes has assumed much greater importance. In addition to performing the required upset in the dies, the cold heading operations may now include single or double extrusion, slotting, punching, trimming, pointing, etc. The wire coatings or finishes must have both the necessary lubricating quality and adherence to prevent galling or undesirable die wear. This necessitates special control of the various types of lubricants that are used and the correct amount of coatings for the type of heading operation involved.

X2.3.10 While lime-soap finishes are widely employed, phosphate finishes are frequently used for the more demanding forming applications.

X2.3.11 Phosphate coated wire finishes are produced from material which has been chemically cleaned, coated with zinc phosphate, and suitably neutralized. The stock may be coated with lime or borax as a carrier if the lubricant is to be applied in the die box. The wire lubricant may be applied by immersing the phosphate coated coils in a dilute soluble soap bath, by pickup of a dry lubricant in the drawing die box, or by a combination of both methods. The drawn finish so produced is particularly beneficial in many severe cold working applications, especially those involving backward extrusion.

X2.3.12 Thermally treated wire can also be supplied cleaned and lime coated or cleaned and phosphate coated at ordered size. Wire phosphate coated at ordered size can be furnished with or without suitable lubricant coatings for subsequent drawing into smaller sizes or for direct use in cold formers. A drawn phosphate finish as discussed in the preceding paragraph, provides a more effective lubrication during cold forming than phosphate coated at finished size.

X2.3.13 Solid die heading machines, especially those used for extrusion heading, require a coating of special consistency, whereas with open or split die heading machines a light coating will perform satisfactorily. Cold heading finishes are varied considerably even for the same type of heading, in order to meet individual cold heading requirements. Those coatings are individual in character and involve manufacturing techniques that differ markedly from conventional wire mill practice where the only consideration is the provision of lubrication essential for the wire drawing operation.

X2.3.14 Size tolerances for wire for cold heading and cold forging are shown in Table 3.

X2.3.15 Mechanical properties for selected steel grades of wire for cold heading and cold forging when thermally treated are shown in Table 11. Whereas it is appropriate to establish mechanical properties for selected compositions of thermally treated carbon steel rods and bars, mechanical properties of wire drawn directly from rods or bars are substantially influenced by the amount of reduction in drawing the wire. The reduction is dependent on the incremental availability of nominal rod and bar sizes as well as the influence of size tolerances. Accordingly no values are included in Table 11 for wire drawn from annealed or spheroidize annealed rods or bars. Certain steel grades are available with differences in deoxidation practices. Suitable allowances for aluminum killed steel and rimmed steel are incorporated in the footnote to Table 11. The amount of reduction prior to thermal treatment, the size tolerance of the intermediate thermally treated wire, and the required percent reduction to final size which progressively increases as the final wire size decreases, influence the mechanical properties. An appropriate adjustment in values for annealed in process and spheroidize annealed in process wire as a function of size is included in the footnote to Table 11.

X2.3.16 Chemical compositions particularly suited to wire for cold heading and cold forging have been developed. For carbon steels these are included in Table 4 and for alloy steels in Table 7.

X2.3.17 Cold Heading and Cold Forging Wire have five application variations as follows:

X2.3.17.1 Cold Heading,
X2.3.17.2 Recessed Head,
X2.3.17.3 Socket Head,
X2.3.17.4 Scrapless Nut, and
X2.3.17.5 Tubular Rivet.

X2.3.18 Each of these variations is intended to be well suited to the fabrication of a particular fastener type and fastener manufacturing method.

X2.3.19 Fastener fabrication includes a wide variety of methods and complexity of machines and tooling. The simplest is a single die, single blow machine, common to the nail machines, but also used for simple shapes such as certain rivets. Single die, two blow machines which first gather stock, then rotate the punch, and strike again, are widely used for larger headed rivets and most machine screws and tapping screws. By partitioning the cold work in two separate die cavities, progressively and selectively deforming the raw material, it is thus possible to produce larger overall deformations or upset, of more complex shapes, without fracture.

X2.3.20 Two die three blow machines permit extruding of the shank, thereby utilizing a larger diameter starting raw material, accommodating the production of larger heads without as much upsetting; or permitting the use of hard drawn wire where annealed material would otherwise have been required. Progressive headers can include six or more stations permitting
the cold forged production of very complex configurations which otherwise would require machining or a combination of forming and machining for their manufacture. Accordingly, it is not appropriate to merely examine the geometry of a finished fastener to establish the appropriate raw material; for example, hard drawn, wire drawn from annealed rod or bar, or spheroidize annealed in process wire. The method of manufacture is also required information, as is the steel processing for a particular application. Communication between the steel supplier and the fastener producer is, therefore, of paramount importance to avoid the use of raw material which is unnecessarily costly on the one hand or inadequately processed on the other.

X2.3.21 Cold Heading Wire is produced by specially controlled manufacturing practices to provide satisfactory quality for heading, forging, and rolling threading. The wire is subject to mill tests and inspection for internal soundness, control of chemical composition, and freedom from detrimental surface imperfections.

X2.3.22 In many cases, the threads of bolts, screws, studs, etc., are cold formed by an operation known as roll threading. This consists of rolling the shank between rolling dies to provide the particular thread form required. Experience has shown that detrimental internal imperfections and detrimental surface imperfections in the wire will result in a crushed condition or imperfect thread which renders the product unfit for use. Therefore, particular care is required in the manufacture of the wire to provide freedom from detrimental imperfections. Precautions are also required of the fabricators in setting up and adjusting roll threading equipment. Faulty set up or adjustment can produce defective threads even when the wire is of proper quality.

X2.3.23 Hard drawn low carbon and medium low carbon steel wire is sometimes successfully used for simple two-blow upsets or for standard trimmed hexagon head cap screws. As upsetting becomes progressively more demanding, wire drawn from annealed or spheroidized annealed rods is more appropriate. For demanding applications, annealed in process or spheroidize annealed in process wire is required. For thermally treated in process wire, the final drawing operation may be performed by the wire supplier or incorporated into the cold heading operation by drawing in process in tandem with that operation. Cold Heading wire is not appropriate for recessed head or socket head application.

X2.3.24 Recessed Head Wire is employed when screw heads incorporate a recess configuration such as a crossed or square recess. This wire involves more exacting precautions and controls than Cold Heading wire, such as improved surface quality and special wire processing. Exacting precautions and controls are necessary in the selection and internal soundness of the steel and in the preparation of billets for surface quality. Special attention to rod rolling and to inspection of the rods is essential. In order to provide wire that will be soft enough to withstand the very severe cold forming operations, wire for all types of recess head screws is generally spheroidize annealed in process or spheroidize annealed at finished size, with the final drawing incorporated into the heading operation by drawing in process in tandem with that operation. When spheroidize annealed at finished size wire is so employed, the fastener producer should ensure that the final reduction is not excessive.

X2.3.25 Socket Head Wire is similar to Recessed Head Wire but is intended for the deep sockets attendant with hexagon and Torx® and similar internal drives, requiring still more exacting processing and controls to accommodate the substantially heavier deformation.

X2.3.26 Scrapless Nut Wire is produced by closely controlled manufacturing practices, and subjected to mill tests and inspection designed to provide internal soundness and freedom from detrimental surface imperfections, thus providing satisfactory cold heading, cold expanding, cold punching, and thread tapping characteristics.

X2.3.26.1 This wire is produced for the manufacture of various shaped nuts, which are made in continuous operation on heading machines. The cold heading operation in the production of scrapless nuts is very severe, and the wire is specially prepared for that purpose.

X2.3.27 Low and medium low carbon hard drawn wire or wire drawn from annealed rods or bars is employed, depending on the severity of deformation. Medium carbon wire is normally drawn from annealed or spheroidize bars or rods, or produced annealed in process. For nuts not requiring a final heat treatment, the attainment of minimum required nut proof loads is partially dependent on the raw material, the selection of an appropriate steel grade, and the amount of wire reduction.

X2.3.28 Tubular Rivet Wire is suitable for cold heading and backward extruding the hole in the shank during cold heading. In order to obtain the properties essential for the production of tubular rivets, the wire is spheroidize annealed in process but with a final redrawing operation somewhat heavier than normal to prevent buckling in the extruding operations. Accordingly, the mechanical properties shown in Table 11 may not always be appropriate for spheroidize annealed in process tubular rivet wire. Wire may also be furnished spheroidize annealed at finished size with the final drawing incorporated into the heading operation by drawing in tandem with that operation. Wire finish to accommodate the individual conditions of severe cold extruding and cold heading is an important consideration. Tubular Rivet wire is normally produced from low carbon aluminum killed steel.
X3. BORON CONTENT IN CARBON STEELS

X3.1 Boron is extremely effective as a hardening agent in carbon steels, contributing hardenability which generally exceeds the result of many commercial alloying elements. It does not adversely affect the formability or machinability (see Note X3.1) of plain carbon steels. Actually, the reverse is true since boron permits the use of lower carbon content which contributes to improved formability and machinability (see Note X3.1).

X3.2 In its early development, some unsatisfactory results produced product which did not have uniform hardness or toughness along with reduced ability to resist delayed fracture. However, many of these problems were overcome by exhaustive research which demonstrated that for boron to be effective as an alloying agent, it must be in solid solution in a composition range of 0.0005 % to 0.003 %. During deoxidation, failure to tie up the free nitrogen results in the formation of boron nitrides which will prevent the boron from being available for hardening. Research also revealed boron content in excess of 0.003 % has a detrimental effect on impact strength because of the precipitation of excess boron as iron borocarbide in the grain boundaries.

X3.3 Many European steels contain higher boron levels than in North America. ISO 898-1 addresses this issue by the following statement: “Boron content can reach 0.005 % provided that noneffective boron is controlled by addition of titanium and/or aluminum.” Boron content is not to be determined by product analysis; only the ladle analysis shall be used.

Note: X3.1—When producing a boron steel, titanium and/or aluminum is added and the resulting product is subjected to thermal processing. These two additions are designed to tie up nitrogen to stop it from reacting with boron. The resulting free boron is available to provide excellent hardenability in steel. Both titanium and aluminum nitrides reduce the machinability of the steel, however, when the nitrogen becomes tied up, the formability of the steel is improved.

X4. SILICON AND ALUMINUM

X4.1 Silicon and aluminum act as somewhat similar elements with respect to their behavior when added during the steel making process. They both have a high affinity for oxygen and are, therefore, used to deoxidize or “kill” the steel. Deoxidation or “killing” is a process by which a strong deoxidizing element is added to the steel to react with the remaining oxygen in the bath to prevent any further reaction between carbon and oxygen. When carbon and oxygen react in the bath a violent boiling action occurs which removes carbon from the steel. When the bath or heat reaches the desired carbon content for the grade being produced, the carbon-oxygen reaction must be stopped quickly to prevent further elimination of carbon. This addition is accomplished by the addition of deoxidizers such as silicon and aluminum which have a greater affinity for oxygen than does carbon. This effectively removes oxygen, eliminating the “carbon boil” and killing the heat. Elements other than silicon and aluminum can be used, but these are the most common.

X4.2 Silicon and aluminum can be added together or individually. This is determined by the type of steel desired. If silicon only is added, that particular batch of steel is referred to as a silicon killed coarse grain practice grade because silicon acts as a deoxidizer without the formation of fine precipitates allowing the formation of large or coarse austenitic grains. Austenitic grain size is not usually a factor for consideration in cold forming, but has a significant effect in subsequent fastener heat treatment. Aluminum, on the other hand, not only deoxidizes the steel, but also refines the grain size. Like silicon, aluminum removes oxygen from the bath, effectively killing the heat. Aluminum also reacts with nitrogen in the steel to form aluminum nitride particles which precipitate both at the grain boundaries and within the austenitic grains thus restricting the size of the grains; even when the steel is reheated for carburizing or neutral hardening, hence the term fine grain. When aluminum only is added, the steel is referred to as aluminum killed, fine grain. A third group of steels are referred to as silicon killed, fine grain. In steels of this type, silicon is added as the deoxidizer followed by the addition of aluminum for grain size control.

X4.3 In the two types where silicon is added, the silicon content can have several ranges with the most common being 0.15 % to 0.30 %. When aluminum is added to these steels for grain size control, the aluminum content is generally in the 0.015 % to 0.030 % range. The aluminum content in fully aluminum killed steels is generally 0.015 % to 0.055 %, somewhat higher on average since the aluminum must both deoxidize and control grain size at the same time.

X4.4 In selecting the type of deoxidation practice for a particular carbon grade of steel to be used in fastener manufacturing, a number of factors should be considered, such as, heat treated property requirements, heat treat conditions, fastener size, and steel availability, to name a few. Silicon acts as a ferrite strengthenener and, therefore, in the absence of aluminum, has somewhat greater Hardenability. For the same carbon grade and heat treat conditions with and without aluminum, complete transformation of the fastener core during heat treatment can take place in a larger section using a coarse grain steel. The disadvantage of silicon killed steels can be reflected in reduced ductility and tool life during cold heading because of its ferrite strengthening characteristic. Aluminum killed steels are usually more formable and hence provide somewhat improved tool life but reduced heat treatment response during
heading, particularly in larger size fasteners. For this reason, the recommended maximum diameter for oil quenched alumi-
num killed carbon grades is typically 0.190 in.

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